NAC flight unit 2 calibration summary log
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8/20/08

Formats for the calibration data:

The .ddd images are 8-bit raw format from the GSE, with an image of even columns first and an image of odd columns second. The images were taken in mode 0, mode 10, and mode 30.

Mode 0 images use companding tables lin1 (straight DN except it rolls over to 0 at 256, 512, etc), lin16 (image is DN/16 and saturates at DN/16=255), and sqroot. The sqroot companding table takes the 12-bit DN and converts it to 8 bits using the first table given in the last worksheet ("compand") of this workbook. Each .ddd mode 0 image has twice as many lines as it should with the even columns first and the odd columns second. Interleaved images have filenames like N12gQa0i.ddd, and are post processed to have the even and odd columns properly Mixed. FITS images have filenames like N12gQa0i.fit, and are interleaved in FITS standard astronomical format. In mode 0, the hardware subtracts the A offset value from the (zero based counting) even columns and the B offset value from the odd columns.

Mode 10 .ddd images are even more complex. The even columns (zero based counting) are saved in full 12-bit form, with values 0-4095. The odd columns are saved in 4-bit form, with values 0-15. The 12 bit and 4 bit values are packed into two 8-bit words in the raw .ddd image. Mode 30 is the same as mode 10 except the 12-bit data is kept for the the odd columns and 4-bit for the even columns. In the lab, a mode 30 image was taken for each mode 10 image, so the full 12 bits would be available for all columns. The raw .ddd files are difficult to interpret and I recommend using only the FITS files for analysis of mode 10 and mode 30 images. Each FITS file is made from one mode 10 raw image and one mode 30 raw image. The name of the FITS file is derived from the mode 10 image. For example, FITS image N20cSd0.i12.fit is derived from mode 10 image N20cSd0.ddd and mode 30 image N20cSe0.ddd. In mode 10 and mode 30, the companding table and the A and B offset values are not used.

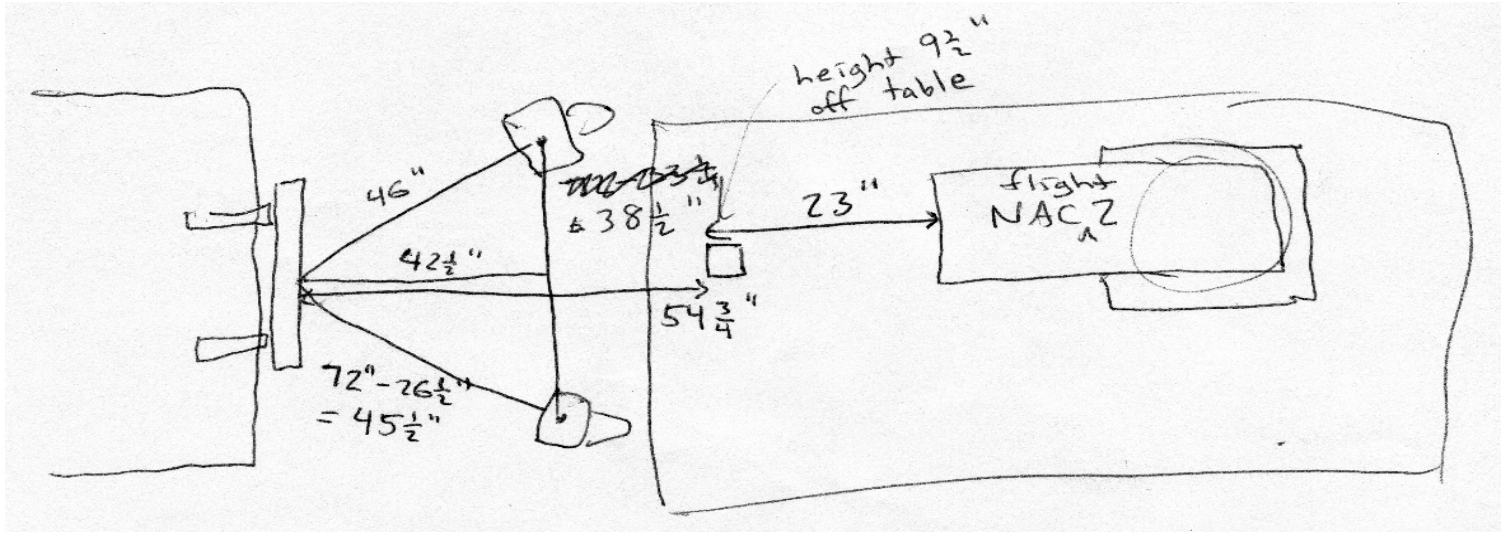
All of the images described in this workbook have 128 lines, with 896 lines of preroll for the GSE. In theory, the GSE is capable of taking images with more lines, but we took a number of bad images with more than 128 lines and we were not successful in taking good ones.

Raw NAC calibration file naming convention is http://lroc.sese.asu.edu/WORK/CALB/NAC1/SD/LROC-namingconvention.doc

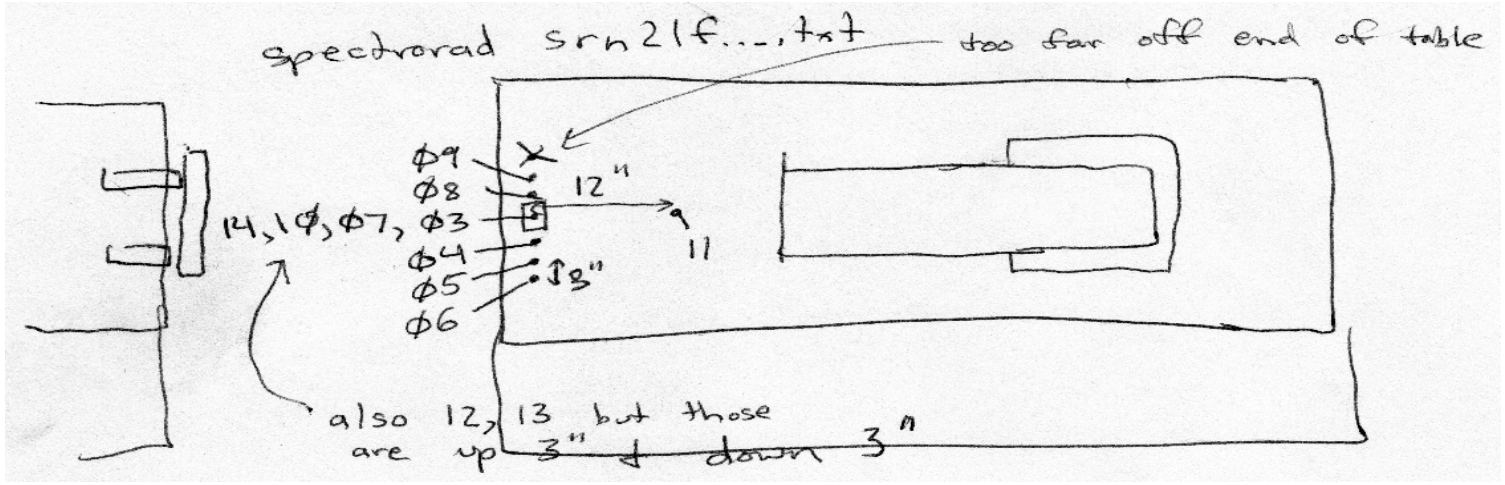
NAC 2 Calibration Tests

Flat field
Flat field with source of ghost obscured by black plate
Detector characterization test with QTH and sphere with 4 inch aperture
Detector characterization test with QTH and sphere with 4 inch aperture at different DAC levels
Responsivity as a function of wavelength up to a constant
Stray light with sphere with 4 inch aperture and 1 inch aperture and Xe lamp
Large angle stray light with direct Xe lamp
Leaked light with white LED flashlight shining into various spots
Geometric calibration

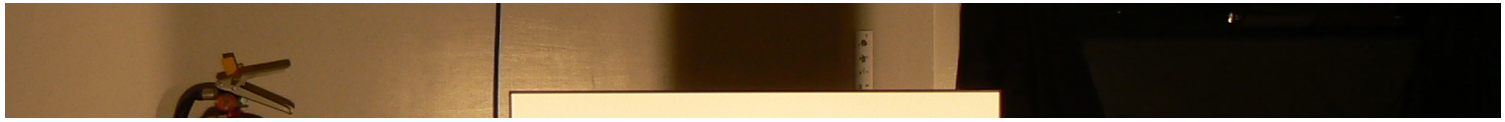
NACFU2 flat field calibration with photo flood lamps and Spectralon panel

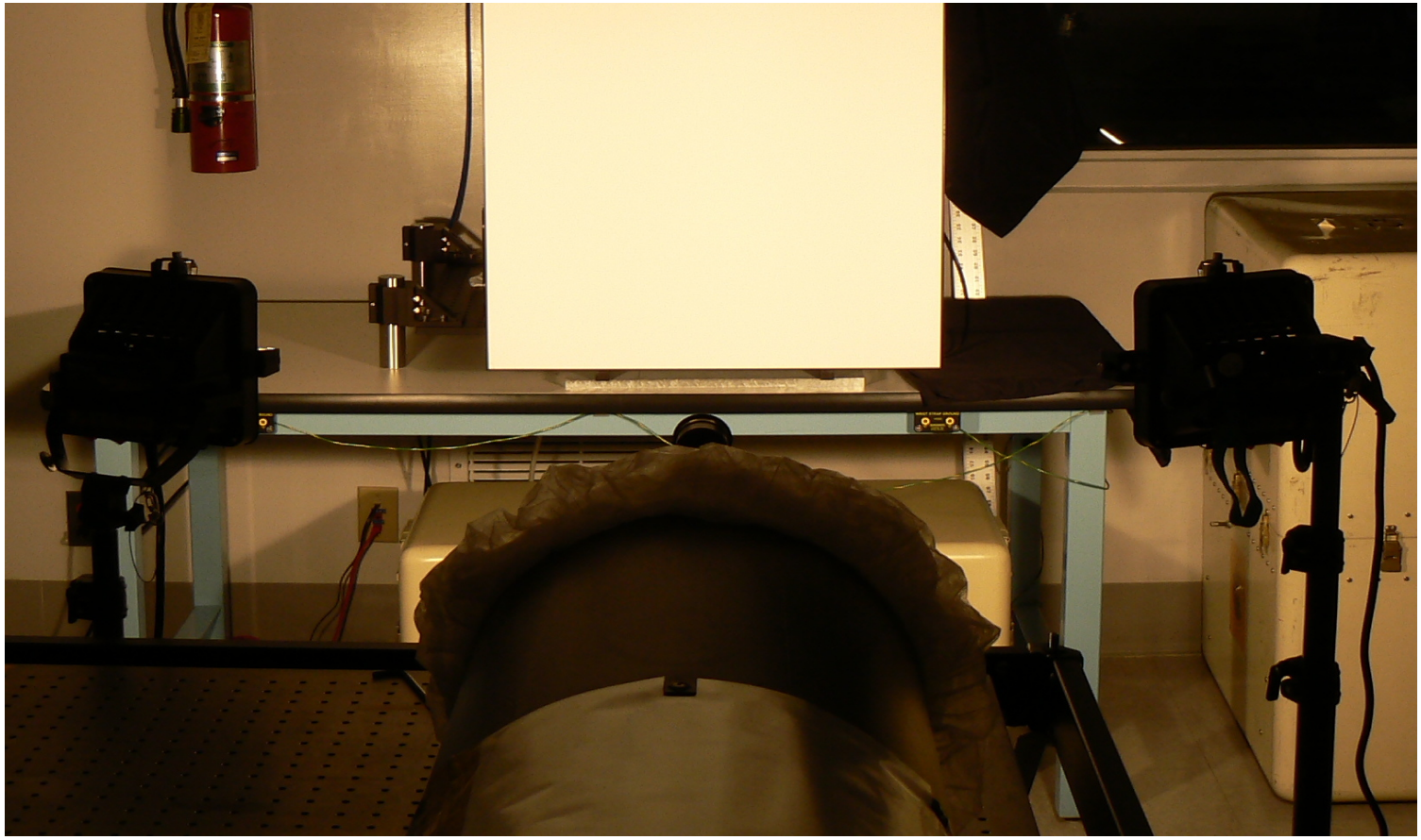


The spectroradiometer was moved over a grid before the flat field measurement, as shown in the drawing below.



Data were taken 4/8/2008





For darks, the NAC was shuttered, plus the 24”x24” black plate was put in front of the shuttered aperture.
The shutter used for darks was not the white cap shown in the picture above, but rather the opaque silvery plastic
(Llumalloy, I believe) cap made for NAC 1.

The two photo flood lamps provide very bright and very uniform illumination of the Spectralon panel. The photo flood lamps are driven directly by AC wall current, and they suffer from 3 kinds of variability:
1. Variability of the AC wall current voltage amplitude over tens of minutes to hours, making the overall brightness nonrepeatable by a few percent.
2. The actual 120 Hz variation in lamp filament temperature due to the 120 Hz variation in electric power due to the 60 Hz variation in voltage. This gives rise to horizontal stripes in the images with an amplitude of about 3%.
3. The lamps are very hot and one sees heat waves rising from them. The lensing causes variability in one photo lamp with respect to the other. This leads to gradients of ~1% in the panel uniformity, varying with a timescale of a couple of tenths of a second. This averages out to no gradient over many lines and many images.

For flat field calculations, the mode 10 and mode 30 data is particularly valuable because it has the full

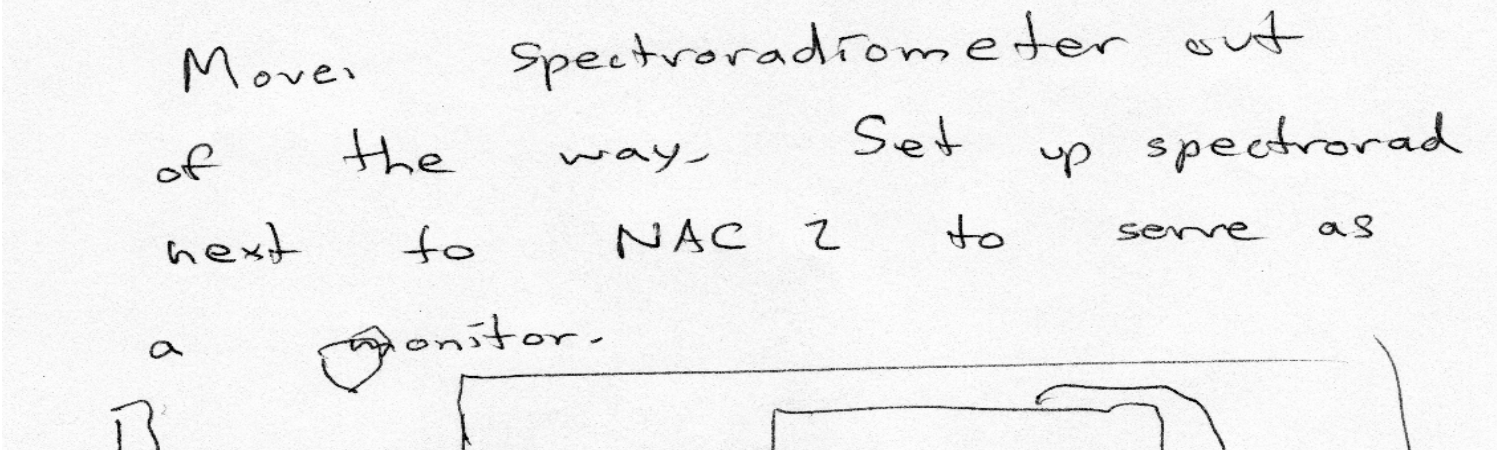
12 bits of accuracy in DN. For darks, of course, mode 0, lin1 data is just as good because it gives fully accurate DN for DN<256. Bright images in mode 0, lin16 are not as accurate because the images are entirely multiples of 16 DN. Unfortunately, for these data we only have mode 0, lin16, because the mode 10 and mode 30 images have 1280 lines and we were not able to get good images from the GSE that had more than 128 lines.

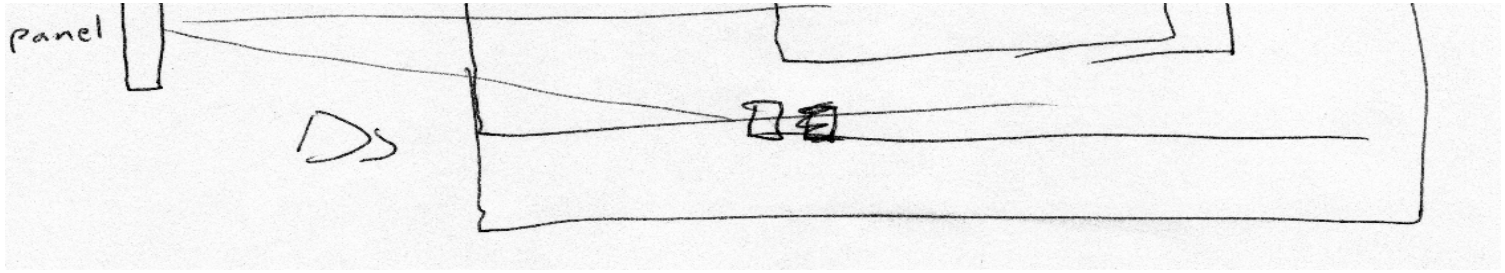
Spectroradiometer scans are taken to verify that the panel is flat and to monitor brightness changes with time.
The spectroradiometer is accurate 400-700 nm **except** one has to multiply the measured value by a factor of 2.4 to get an accurate value.
The spectroradiometer is **not** accurate >700 nm. We believe it is repeatable at all wavelengths, but this has not been carefully verified.

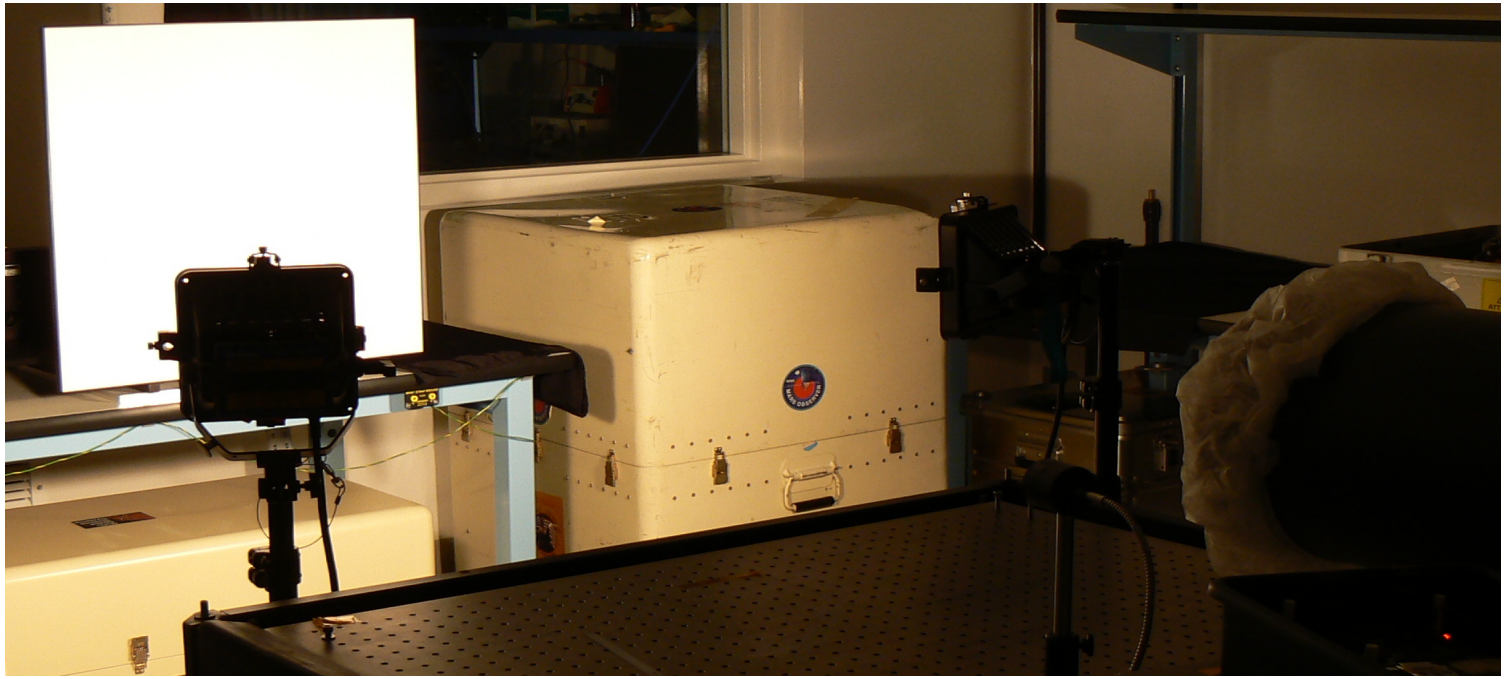
The header note in the .ddd image files is incorrect for the N21sLa images.

Calibration parameters			NAC parameters					
Filename	Dark	Notes	Mode	Companding tat DAC	Dc offset A	Dc offset B	Exp command	Exposure time (ms)
Spectroradiometer scan srn21f00.txt in scope mode, capped (dark)								
Spectroradiometer scan srn21f01.txt capped (dark)								
Spectroradiometer scan srn21f02.txt in scope mode								
Next set of spectroradiometer scans are over a grid given in the second drawing above								
Spectroradiometer scan srn21f03.txt								
Spectroradiometer scan srn21f04.txt								
Spectroradiometer scan srn21f05.txt								
Spectroradiometer scan srn21f06.txt								
Spectroradiometer scan srn21f07.txt								
Spectroradiometer scan srn21f08.txt								
Spectroradiometer scan srn21f09.txt								
Spectroradiometer scan srn21f10.txt								
Spectroradiometer scan srn21f11.txt								
Spectroradiometer scan srn21f12.txt								
Spectroradiometer scan srn21f13.txt								
Spectroradiometer scan srn21f14.txt								

Spectroradiometer was moved out of the way of the NAC, next to the NAC to serve as a monitor, as seen in the drawing and picture below







Spectroradiometer scan srn21tLa00.txt

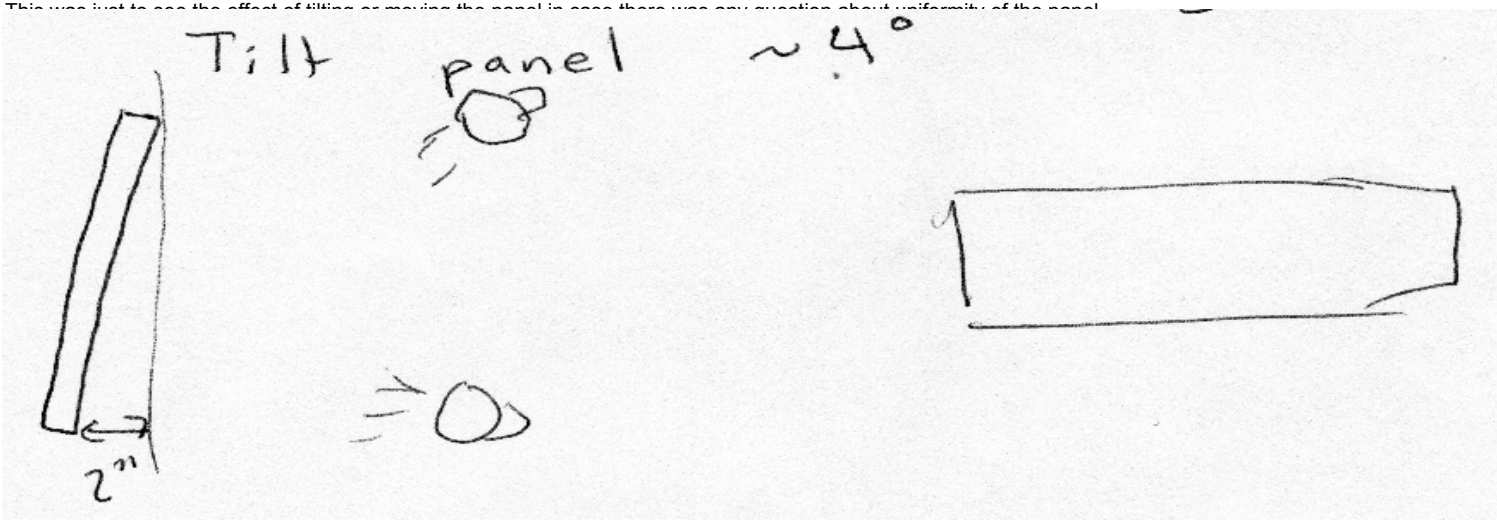
N21dLa0.ddd	NAC shuttered, black plate		0	Lin1	190	39	81	0	0.337
N21dLa1.ddd	NAC shuttered, black plate		0	Lin1	190	39	81	40	0.678
N21dLa2.ddd	NAC shuttered, black plate		0	Lin1	190	39	81	140	1.531
N21dLa3.ddd	NAC shuttered, black plate		0	Lin1	190	39	81	300	2.895
N21dLa4.ddd	NAC shuttered, black plate		0	Lin16	190	39	81	0	0.337
N21dLa5.ddd	NAC shuttered, black plate		0	Lin16	190	39	81	40	0.678
N21dLa6.ddd	NAC shuttered, black plate		0	Lin16	190	39	81	140	1.531
N21dLa7.ddd	NAC shuttered, black plate		0	Lin16	190	39	81	300	2.895
N21dLa8.ddd	NAC shuttered, black plate	Mode 10			190			0	0.337

N21dLa9.ddd	NAC shuttered, black plate	Mode 30		190			0	0.337
N21dLa10.ddd	NAC shuttered, black plate	Mode 10		190			40	0.678
N21dLa11.ddd	NAC shuttered, black plate	Mode 30		190			40	0.678
N21dLa12.ddd	NAC shuttered, black plate	Mode 10		190			140	1.531
N21dLa13.ddd	NAC shuttered, black plate	Mode 30		190			140	1.531
N21dLa14.ddd	NAC shuttered, black plate	Mode 10		190			300	2.895
N21dLa15.ddd	NAC shuttered, black plate	Mode 30		190			300	2.895
Spectroradiometer scan srn21fLa00.txt								
N21fLa0.ddd			0 Lin16	190	39	81	0	0.337
N21fLa1.ddd			0 Lin16	190	39	81	0	0.337
N21fLa2.ddd			0 Lin16	190	39	81	0	0.337

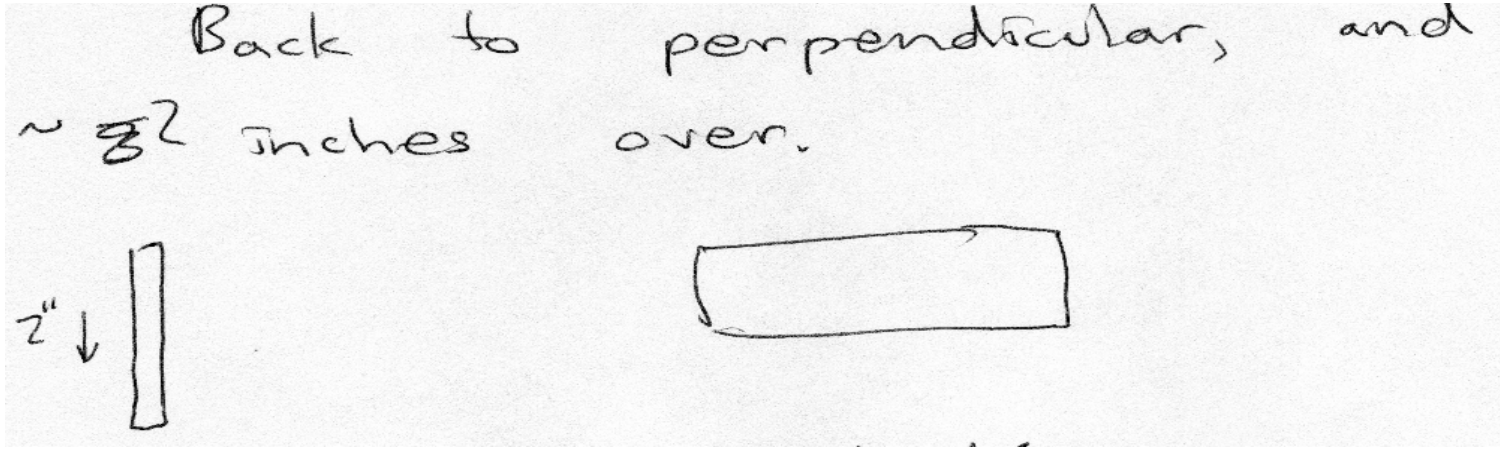
...insert additional filenames and data, starting with page 9 of lab notes http://lroc.sese.asu.edu/WORK/CALB/NAC2/PDF/NAC2-20080408a-CalLog.pdf

N21dLb37.ddd	NAC shuttered, black plate		0 Lin1	190	39	81	300	2.895
N21dLb38.ddd	NAC shuttered, black plate		0 Lin1	190	39	81	300	2.895
N21dLb39.ddd	NAC shuttered, black plate		0 Lin1	190	39	81	300	2.895

Later that day, after the calibration test using the black plate to mask the ghost, we did some brief additional flat field with the panel tilted or moved.
This was just to see the effect of tilting or moving the panel in case there was any question about uniformity of the panel.



N21sLe0.ddd			0 Lin16	190	39	81	300	2.895
N21sLe1.ddd		Mode 10		190			300	2.895
N21sLe2.ddd		Mode 30		190			300	2.895



N21sLf0.ddd			0	Lin16	190	39	81	300	2.895
N21sLf1.ddd		Mode 10			190			300	2.895
N21sLf2.ddd		Mode 30			190			300	2.895
N21dLd0.ddd	NAC shuttered, black plate		0	Lin1	190	39	81	0	0.337
N21dLd1.ddd	NAC shuttered, black plate		0	Lin1	190	39	81	40	0.678
N21dLd2.ddd	NAC shuttered, black plate		0	Lin1	190	39	81	140	1.531
N21dLd3.ddd	NAC shuttered, black plate		0	Lin1	190	39	81	300	2.895

Analysis available as of 7/29/2008
http://lroc.sese.asu.edu/WORK/CALB/NAC2/NAC2-080408-flatfield+straylight/index.html
Some columns of numbers and plots of flat fields are posted on this site.
As of 7/29/2008, some of these numbers and plots should be taken with a grain of salt.
Mode 10 has accurate 12-bit data for even columns and mode 30 has accurate 12-bit data for odd columns.
However, the plots on this website include odd columns in mode 10 and even columns in mode 30, reconstructed from 4-bit data.
These are not reliable.
Also, as of 7/29/2008, the full masked pixel, dark, and offset subtraction for the flight calibration pipeline is not yet implemented.
The flat fields will change slightly from the ones posted on the Web site when the flight pipeline is completed.

NACFU2 flat field with black plate obscuring the ghost on each side

Same setup as the flat field with the two photo lamps and the Spectralon panel, covering it with black cloth or black plate.

Data were taken 4/8/2008

The sources of the ghosts centered at columns ~1000 and ~4000 are just outside the field of view.
The source of each ghost is on the same side of the field of view as that ghost.
Analysis indicated that the images with 5 inches of the white panel covered by the black plate blocks the source of the ghost on that side without Vignetting the signal inside the field of view at all.
The ratio of the full white panel to the white panel with 5 inches covered by the black plate gives the ghost as a fraction of the signal.

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2. The actual 120 Hz variation in lamp filament temperature due to the 120 Hz variation in electric power due to the 60 Hz variation in voltage. This gives rise to horizontal stripes in the images with an amplitude of about 3%.
3. The lamps are very hot and one sees heat waves rising from them. The lensing causes variability in one photo lamp with respect to another. This leads to gradients of ~1% in the panel uniformity, varying with a timescale of a couple of tenths of a second. This averages out to no gradient over many lines and many images.

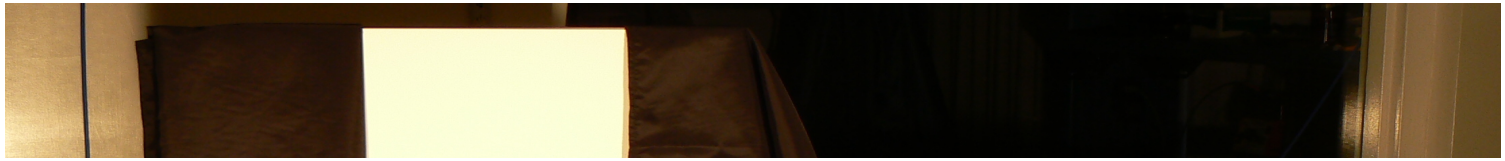
For flat field calculations, the mode 10 and mode 30 data is particularly valuable because it has the full 12 bits of accuracy in DN. For darks, of course, mode 0, lin1 data is just as good because it gives fully accurate DN for DN<256. Bright images in mode 0, lin16 are not as accurate because the images are entirely multiples of 16 DN. This second set of flat field data has good images in mode 10 and mode 30, unlike the first set.

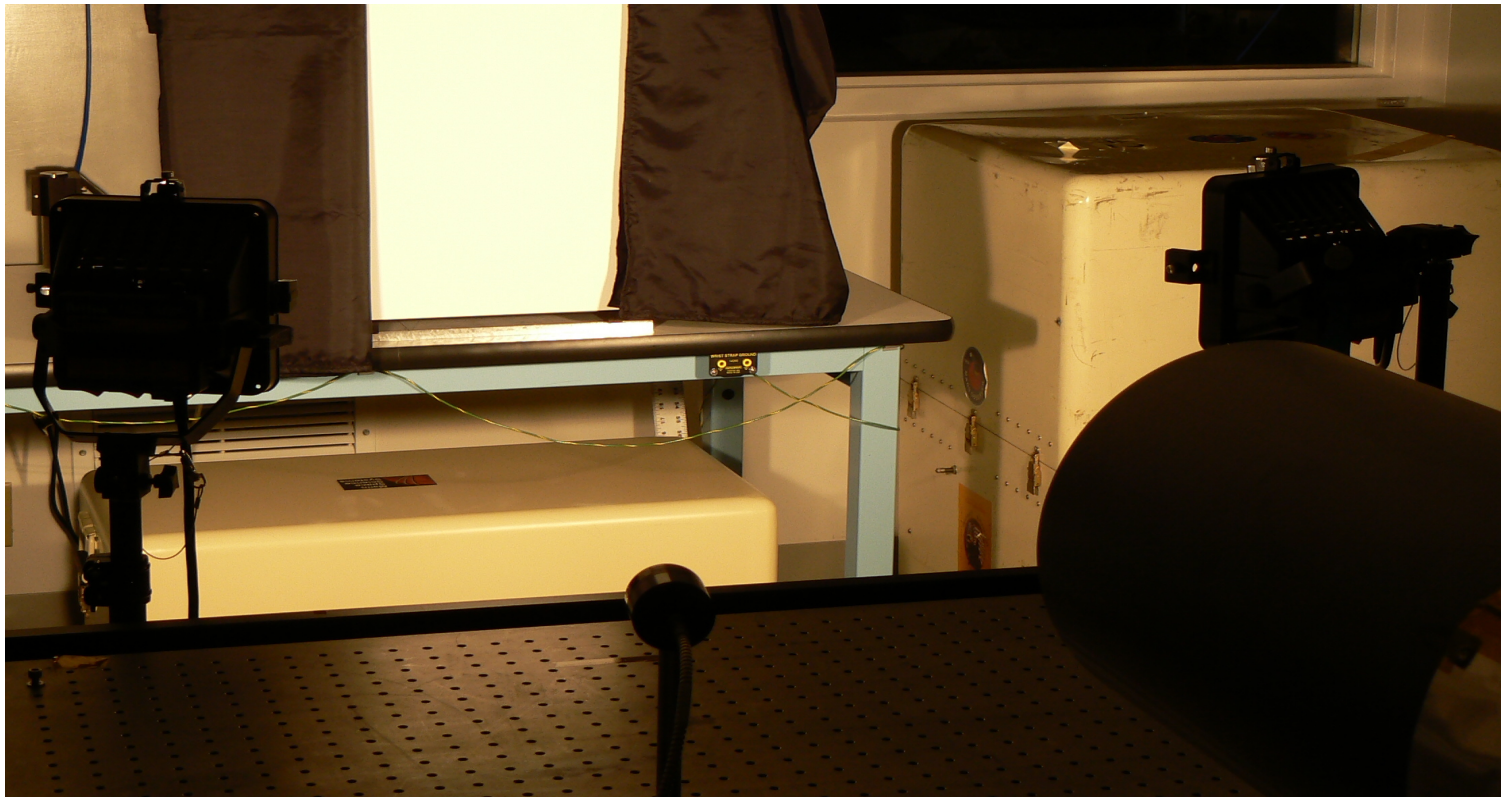
Spectroradiometer scans are taken to verify that the panel is flat and to monitor brightness changes with time.
The spectroradiometer is accurate 400-700 nm **except** one has to multiply the measured value by a factor of 2.4 to get an accurate value.
The spectroradiometer is **not** accurate >700 nm. We believe it is repeatable at all wavelengths, but this has not been carefully verified.

Calibration parameters			NAC parameters						
Filename	Dark	Notes	Mode	Companding tat	DAC	Dc offset A	Dc offset B	Exp command	Exposure time (ms)
N21dLb0.ddd	NAC shuttered, black plate		0	Lin1	190	39	81	0	0.337

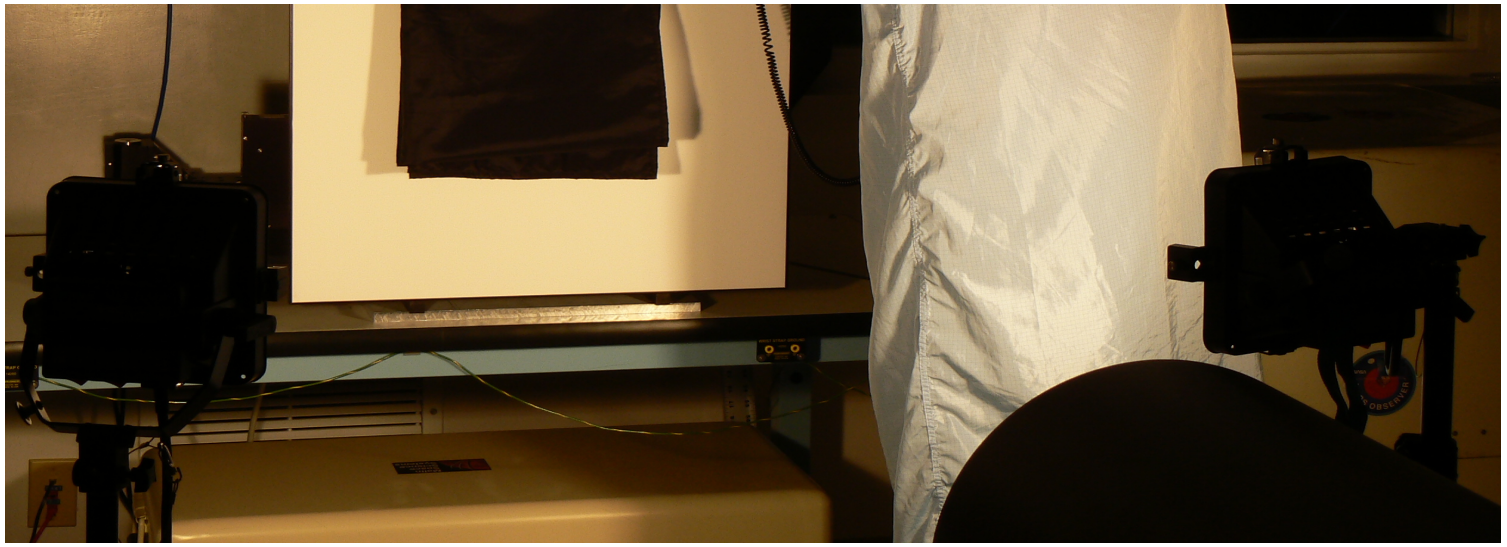
...insert additional filenames and data, starting with page 11 of lab notes http://lroc.sese.asu.edu/WORK/CALB/NAC2/PDF/NAC2-20080408a-CalLog.pdf

N21dLb39.ddd	NAC shuttered, black plate	0	Lin1	190	39	81	300	2.895
Spectroradiometer scan srn21sL	3” strip on each side covered with black cloth							
N21sLa0.ddd	3” strip on each side covered wit	0	Lin16	190	39	81	300	2.895



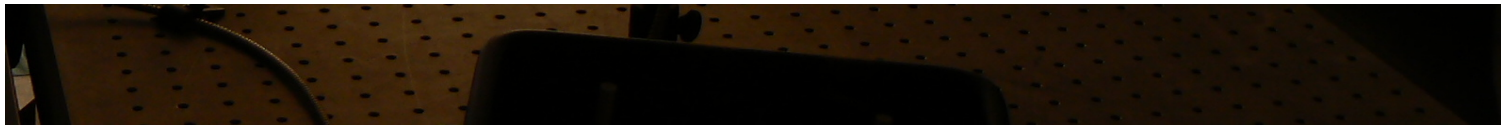


Spectroradiometer scan srn21sL	6” strip on each side covered with black cloth; see picture above							
N21sLa1.ddd	6” strip on each side covered wit	0	Lin16	190	39	81	300	2.895
Spectroradiometer scan srn21sL	Panel uncovered							
N21sLa2.ddd	Panel uncovered	0	Lin16	190	39	81	300	2.895
Spectroradiometer scan srn21sL	18” cloth square in center of panel							
N21sLa3.ddd	18” cloth square in center of pan	0	Lin16	190	39	81	300	2.895



Spectroradiometer scan srn21sL	18” cloth square in center of panel							
N21sLa4.ddd	18” cloth square in center of pan	0	Lin16	190	39	81	300	2.895
Spectroradiometer scan srn21sL	Right half covered with black plate							
N21sLa5.ddd	Right half covered with black pla	0	Lin16	190	39	81	300	2.895
Spectroradiometer scan srn21sL	Right 1/4 covered with black plate							
N21sLa6.ddd	Right 1/4 covered with black plat	0	Lin16	190	39	81	300	2.895
Spectroradiometer scan srn21tLb00.txt capped (dark)								
Spectroradiometer scan srn21tLb01.txt scope mode and capped (dark)								
Spectroradiometer was removed and put back in approximately the same position at this point, but the lamps were not moved.								
Spectroradiometer scan srn21sLb00.txt scope mode and capped (dark)								
Spectroradiometer scan srn21sLb01.txt capped (dark)								
Spectroradiometer scan srn21sL	Panel uncovered							
N21dLc0.ddd	NAC shuttered, black plate	0	Lin1	190	39	81	0	0.337
N21dLc1.ddd	NAC shuttered, black plate	0	Lin1	190	39	81	40	0.678
N21dLc2.ddd	NAC shuttered, black plate	0	Lin1	190	39	81	140	1.531
N21dLc3.ddd	NAC shuttered, black plate	0	Lin1	190	39	81	300	2.895
N21sLb0.ddd	Right 8” covered by black plate	0	Lin16	190	39	81	300	2.895
N21sLb1.ddd	Right 8” covered by black plate Mode 10			190			300	2.895
N21sLb2.ddd	Right 8” covered by black plate Mode 30			190			300	2.895
N21sLb3.ddd	Right 7” covered by black plate	0	Lin16	190	39	81	300	2.895
N21sLb4.ddd	Right 7” covered by black plate Mode 10			190			300	2.895
N21sLb5.ddd	Right 7” covered by black plate Mode 30			190			300	2.895
N21sLb6.ddd	Right 6” covered by black plate	0	Lin16	190	39	81	300	2.895
N21sLb7.ddd	Right 6” covered by black plate Mode 10			190			300	2.895
N21sLb8.ddd	Right 6” covered by black plate Mode 30			190			300	2.895

N21sLb9.ddd	Right 5” covered by black plate		0	Lin16	190	39	81	300	2.895
N21sLb10.ddd	Right 5” covered by black plate	Mode 10			190			300	2.895
N21sLb11.ddd	Right 5” covered by black plate	Mode 30			190			300	2.895
N21sLb12.ddd	Right 4” covered by black plate		0	Lin16	190	39	81	300	2.895
N21sLb13.ddd	Right 4” covered by black plate	Mode 10			190			300	2.895
N21sLb14.ddd	Right 4” covered by black plate	Mode 30			190			300	2.895
N21sLb15.ddd	Right 3” covered by black plate		0	Lin16	190	39	81	300	2.895
N21sLb16.ddd	Right 3” covered by black plate	Mode 10			190			300	2.895
N21sLb17.ddd	Right 3” covered by black plate	Mode 30			190			300	2.895

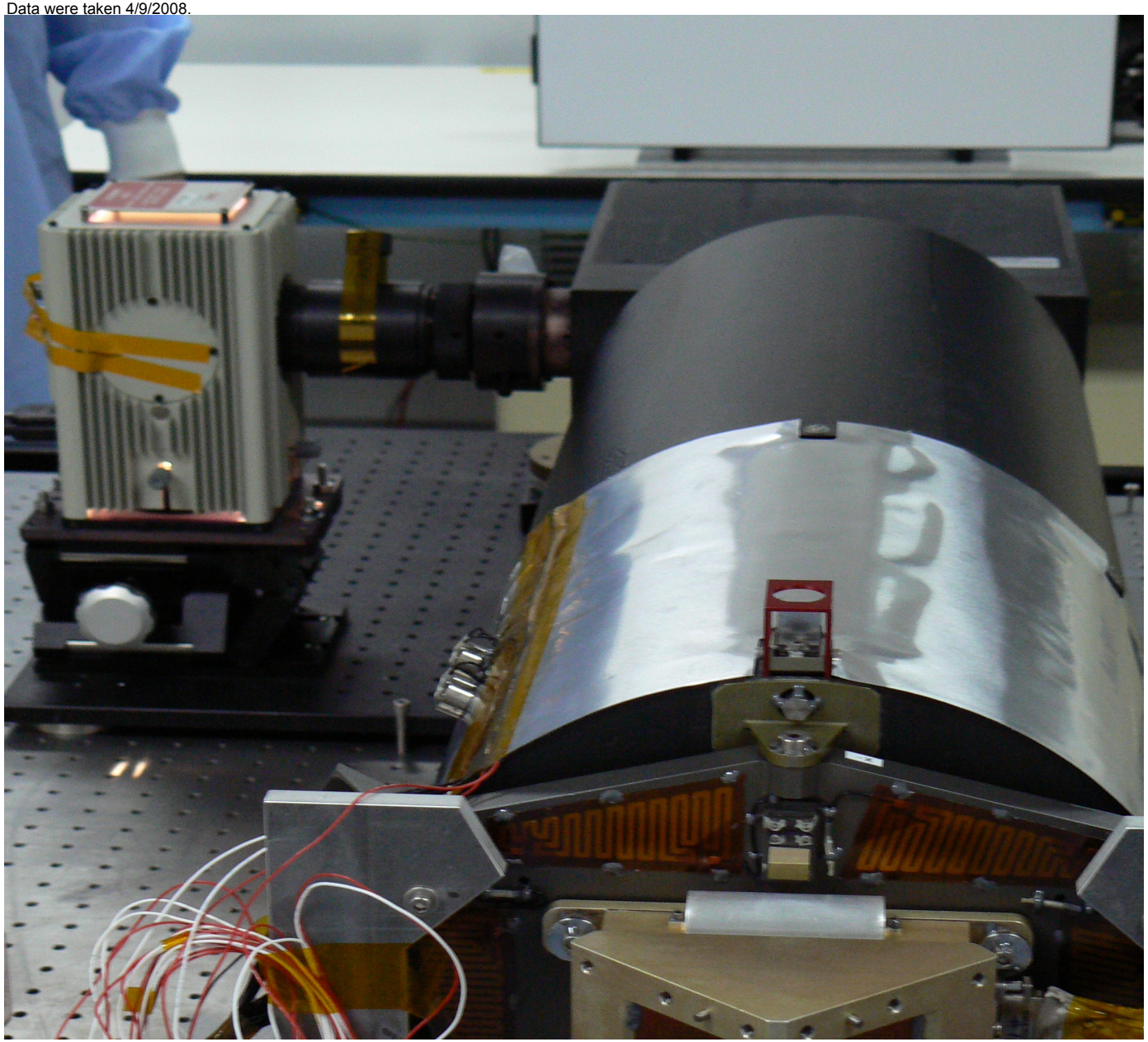


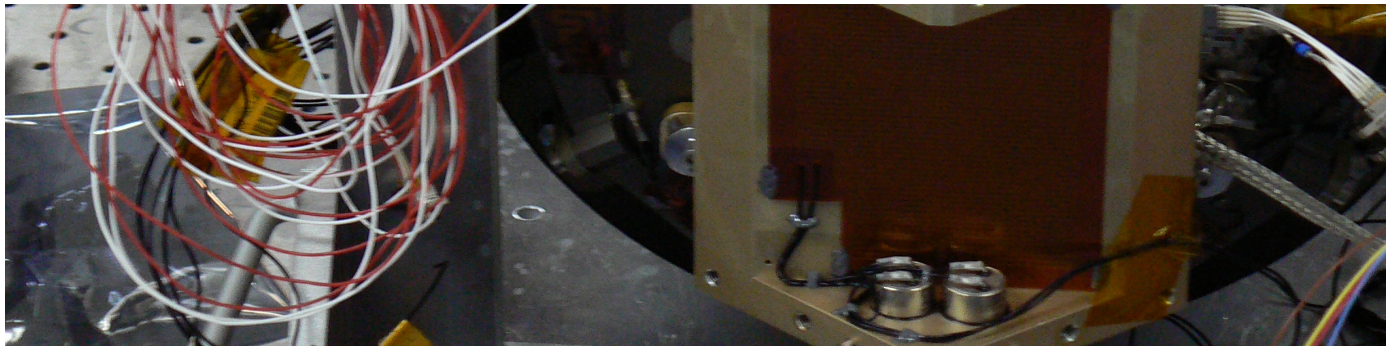
N21sLc0.ddd	Left 8” covered by black plate; s		0	Lin16	190	39	81	300	2.895
N21sLc1.ddd	Left 8” covered by black plate; s	Mode 10			190			300	2.895
N21sLc2.ddd	Left 8” covered by black plate; s	Mode 30			190			300	2.895
N21sLc3.ddd	Left 7” covered by black plate		0	Lin16	190	39	81	300	2.895
N21sLc4.ddd	Left 7” covered by black plate	Mode 10			190			300	2.895
N21sLc5.ddd	Left 7” covered by black plate	Mode 30			190			300	2.895
N21sLc9.ddd	Left 6” covered by black plate		0	Lin16	190	39	81	300	2.895
N21sLc10.ddd	Left 6” covered by black plate	Mode 10			190			300	2.895
N21sLc11.ddd	Left 6” covered by black plate	Mode 30			190			300	2.895
N21sLc12.ddd	Left 5” covered by black plate		0	Lin16	190	39	81	300	2.895
N21sLc13.ddd	Left 5” covered by black plate	Mode 10			190			300	2.895
N21sLc14.ddd	Left 5” covered by black plate	Mode 30			190			300	2.895
N21sLc15.ddd	Left 4” covered by black plate		0	Lin16	190	39	81	300	2.895
N21sLc16.ddd	Left 4” covered by black plate	Mode 10			190			300	2.895
N21sLc17.ddd	Left 4” covered by black plate	Mode 30			190			300	2.895
N21sLc18.ddd	Left 3” covered by black plate		0	Lin16	190	39	81	300	2.895
N21sLc19.ddd	Left 3” covered by black plate	Mode 10			190			300	2.895
N21sLc20.ddd	Left 3” covered by black plate	Mode 30			190			300	2.895
Spectroradiometer scan srn21sL	Left 3” covered by black plate								
N21sLd0.ddd	Panel uncovered		0	Lin16	190	39	81	300	2.895
N21sLd1.ddd	Panel uncovered	Mode 10			190			300	2.895
N21sLd2.ddd	Panel uncovered	Mode 30			190			300	2.895
N21dLd0.ddd	NAC shuttered, black plate		0	Lin1	190	39	81	0	0.337
N21dLd1.ddd	NAC shuttered, black plate		0	Lin1	190	39	81	40	0.678
N21dLd2.ddd	NAC shuttered, black plate		0	Lin1	190	39	81	140	1.531
N21dLd3.ddd	NAC shuttered, black plate		0	Lin1	190	39	81	300	2.895

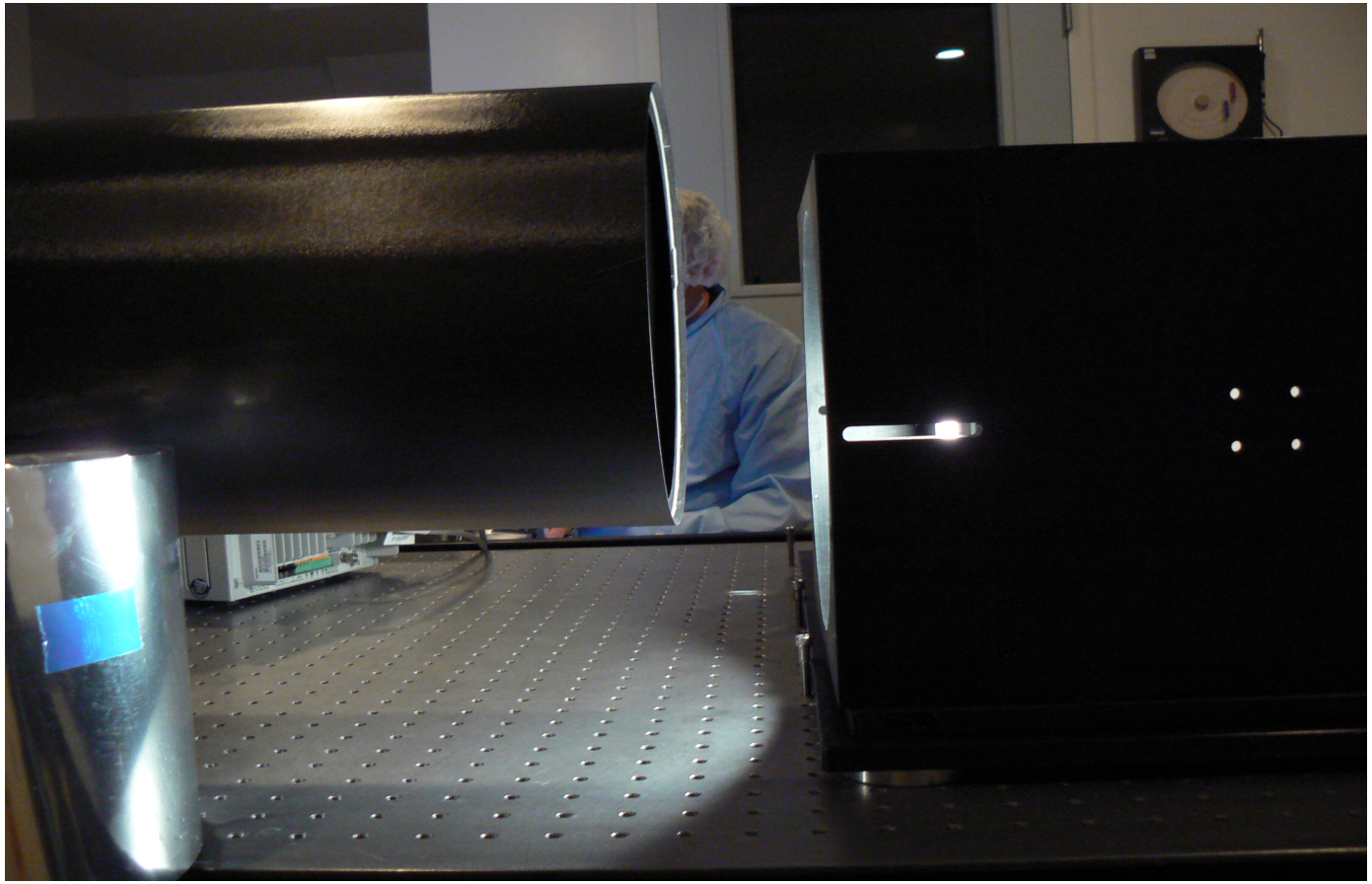
Analysis available as of 7/29/2008
http://lroc.sese.asu.edu/WORK/CALB/NAC2/straylight/index.html
The last two plots on the page are taken from these data and the last plot gives the fraction of the ghost as a function of signal.

NACFU1 detector linearity calibration with QTH lamp and sphere with 4 inch aperture

Data were taken 4/9/2008.







The quartz tungsten halogen (QTH) lamp is powered by a regulated dc current power supply, and the brightness of the

QTH lamp is highly constant with time. The exposure time given in the embedded ascii header of each .ddd file is believed to be highly accurate. In the detector linearity test, images are taken at multiple exposure times. The light source is constant, so it's possible to plot the DN as a function of relative number of photons detected (detector linearity) or line-to-line standard deviation of DN as a function of relative number of photons detected (photon transfer curve, or PTC). Repeating the data set at different lamp current, and dark, allows one to check For exposure time offset as well as DN offset, and to see if the linearity or PTC changes with frame rate. Note that for the NAC, the exposure time always equals the frame time.

The source is a fairly uniform flat field, but it's not vital that it be accurately flat for linearity and PTC.

For detector linearity and PTC calculations, the mode 10 and mode 30 data is particularly valuable because it has the full 12 bits of accuracy in DN. For darks, of course, mode 0, lin1 data is just as good because it gives fully accurate DN for DN<256. Bright images in mode 0, lin16 are not as accurate because the images are entirely multiples of 16 DN.

Calibration parameters			NAC parameters					
Filename	QTH current (A)	Dark Notes	Mode	Companding tal	DAC	Dc offset A	Dc offset B	Exp command	Exposure time (ms)
N20dSa0.ddd		NAC shuttered, room dark, lamp off	0	Lin1	190	26	71	3200	27.617
N20dSa1.ddd		NAC shuttered, room dark, lamp off	0	Lin1	190	26	71	0	0.337
N20dSa2.ddd		NAC shuttered, room dark, lamp off	0	Lin1	190	26	71	400	3.747
N20dSa3.ddd		NAC shuttered, room dark, lamp off	0	Lin1	190	26	71	800	7.157
N20dSa4.ddd		NAC shuttered, room dark, lamp off	0	Lin1	190	26	71	50	0.764
N20dSa5.ddd		NAC shuttered, room dark, lamp off	0	Lin1	190	26	71	1800	15.682
N20dSa6.ddd		NAC shuttered, room dark, lamp off	0	Lin1	190	26	71	100	1.19
N20dSa7.ddd		NAC shuttered, room dark, lamp off	0	Lin1	190	26	71	4095	35.246
N20dSa8.ddd		NAC shuttered, room dark, lamp off	0	Lin1	190	26	71	200	2.042
N20dSa9.ddd		NAC shuttered, room dark, lamp off	0	Lin1	190	26	71	3600	31.027
N20dSa10.ddd		NAC shuttered, room dark, lamp off	0	Lin1	190	26	71	1200	10.567
N20dSa11.ddd		NAC shuttered, room dark, lamp off	0	Lin1	190	26	71	2400	20.797
N20dSa12.ddd		NAC shuttered, room dark, lamp off	0	Lin1	190	26	71	2800	24.207
N20dSa13.ddd		NAC shuttered, room dark, lamp off	0	Lin1	190	26	71	3000	25.912
N20dSa14.ddd		NAC shuttered, room dark, lamp off	0	Lin1	190	26	71	3400	29.322
N20cSd0.ddd	7.2		10		190			3200	27.617
N20cSd1.ddd	7.2		10		190			0	0.337
N20cSd2.ddd	7.2		10		190			400	3.747
N20cSd3.ddd	7.2		10		190			800	7.157
N20cSd4.ddd	7.2		10		190			50	0.764
N20cSd5.ddd	7.2		10		190			1800	15.682
N20cSd6.ddd	7.2		10		190			100	1.19
N20cSd7.ddd	7.2		10		190			4095	35.246
N20cSd8.ddd	7.2		10		190			200	2.042
N20cSd9.ddd	7.2		10		190			3600	31.027
N20cSd10.ddd	7.2		10		190			1200	10.567
N20cSd11.ddd	7.2		10		190			2400	20.797
N20cSd12.ddd	7.2		10		190			2800	24.207
N20cSd13.ddd	7.2		10		190			3000	25.912
N20cSd14.ddd	7.2		10		190			3400	29.322
N20cSe0.ddd	7.2		30		190			3200	27.617
N20cSe1.ddd	7.2		30		190			0	0.337

N20cSe2.ddd	7.2		30		190		400	3.747
N20cSe3.ddd	7.2		30		190		800	7.157
N20cSe4.ddd	7.2		30		190		50	0.764
N20cSe5.ddd	7.2		30		190		1800	15.682
N20cSe6.ddd	7.2		30		190		100	1.19
N20cSe7.ddd	7.2		30		190		4095	35.246
N20cSe8.ddd	7.2		30		190		200	2.042
N20cSe9.ddd	7.2		30		190		3600	31.027
N20cSe10.ddd	7.2		30		190		1200	10.567
N20cSe11.ddd	7.2		30		190		2400	20.797
N20cSe12.ddd	7.2		30		190		2800	24.207
N20cSe13.ddd	7.2		30		190		3000	25.912
N20cSe14.ddd	7.2		30		190		3400	29.322
N20cSf0.ddd	5.5		10		190		3200	27.617
N20cSf1.ddd	5.5		10		190		0	0.337
N20cSf2.ddd	5.5		10		190		400	3.747
N20cSf3.ddd	5.5		10		190		800	7.157
N20cSf4.ddd	5.5		10		190		50	0.764
N20cSf5.ddd	5.5		10		190		1800	15.682
N20cSf6.ddd	5.5		10		190		100	1.19
N20cSf7.ddd	5.5		10		190		4095	35.246
N20cSf8.ddd	5.5		10		190		200	2.042
N20cSf9.ddd	5.5		10		190		3600	31.027
N20cSf10.ddd	5.5		10		190		1200	10.567
N20cSf11.ddd	5.5		10		190		2400	20.797
N20cSf12.ddd	5.5		10		190		2800	24.207
N20cSf13.ddd	5.5		10		190		3000	25.912
N20cSf14.ddd	5.5		10		190		3400	29.322
N20cSg0.ddd	5.5		30		190		3200	27.617
N20cSg1.ddd	5.5		30		190		0	0.337
N20cSg2.ddd	5.5		30		190		400	3.747
N20cSg3.ddd	5.5		30		190		800	7.157
N20cSg4.ddd	5.5		30		190		50	0.764
N20cSg5.ddd	5.5		30		190		1800	15.682
N20cSg6.ddd	5.5		30		190		100	1.19
N20cSg7.ddd	5.5		30		190		4095	35.246
N20cSg8.ddd	5.5		30		190		200	2.042
N20cSg9.ddd	5.5		30		190		3600	31.027
N20cSg10.ddd	5.5		30		190		1200	10.567
N20cSg11.ddd	5.5		30		190		2400	20.797
N20cSg12.ddd	5.5		30		190		2800	24.207
N20cSg13.ddd	5.5		30		190		3000	25.912
N20cSg14.ddd	5.5		30		190		3400	29.322
N20dSb0.ddd		NAC shuttered, room dark, lamp off	0	Lin1	190	26	71	3200	27.617
N20dSb1.ddd		NAC shuttered, room dark, lamp off	0	Lin1	190	26	71	0	0.337
N20dSb2.ddd		NAC shuttered, room dark, lamp off	0	Lin1	190	26	71	400	3.747
N20dSb3.ddd		NAC shuttered, room dark, lamp off	0	Lin1	190	26	71	800	7.157
N20dSb4.ddd		NAC shuttered, room dark, lamp off	0	Lin1	190	26	71	50	0.764
N20dSb5.ddd		NAC shuttered, room dark, lamp off	0	Lin1	190	26	71	1800	15.682

N20dSb6.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	26	71	100	1.19
N20dSb7.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	26	71	4095	35.246
N20dSb8.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	26	71	200	2.042
N20dSb9.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	26	71	3600	31.027
N20dSb10.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	26	71	1200	10.567
N20dSb11.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	26	71	2400	20.797
N20dSb12.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	26	71	2800	24.207
N20dSb13.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	26	71	3000	25.912
N20dSb14.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	26	71	3400	29.322
N20dSc0.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	60	104	3200	27.617
N20dSc1.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	60	104	0	0.337
N20dSc2.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	60	104	400	3.747
N20dSc3.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	60	104	800	7.157
N20dSc4.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	60	104	50	0.764
N20dSc5.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	60	104	1800	15.682
N20dSc6.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	60	104	100	1.19
N20dSc7.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	60	104	4095	35.246
N20dSc8.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	60	104	200	2.042
N20dSc9.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	60	104	3600	31.027
N20dSc10.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	60	104	1200	10.567
N20dSc11.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	60	104	2400	20.797
N20dSc12.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	60	104	2800	24.207
N20dSc13.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	60	104	3000	25.912
N20dSc14.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	60	104	3400	29.322
N20dSd0.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	26	71	3200	27.617
N20dSd1.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	26	71	0	0.337
N20dSd2.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	26	71	400	3.747
N20dSd3.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	26	71	800	7.157
N20dSd4.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	26	71	50	0.764
N20dSd5.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	26	71	1800	15.682
N20dSd6.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	26	71	100	1.19
N20dSd7.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	26	71	4095	35.246
N20dSd8.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	26	71	200	2.042
N20dSd9.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	26	71	3600	31.027
N20dSd10.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	26	71	1200	10.567
N20dSd11.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	26	71	2400	20.797
N20dSd12.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	26	71	2800	24.207
N20dSd13.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	26	71	3000	25.912
N20dSd14.ddd	NAC shuttered, room dark, lamp off	0 Lin1	190	26	71	3400	29.322
N20tSh0.ddd	4.5	0 Lin1	190	26	71	3200	27.617
N20tSh1.ddd	4.5	0 Lin1	190	26	71	0	0.337
N20tSh2.ddd	4.5	0 Lin1	190	26	71	400	3.747
N20tSh3.ddd	4.5	0 Lin1	190	26	71	800	7.157
N20tSh4.ddd	4.5	0 Lin1	190	26	71	50	0.764
N20tSh5.ddd	4.5	0 Lin1	190	26	71	1800	15.682
N20tSh6.ddd	4.5	0 Lin1	190	26	71	100	1.19
N20tSh7.ddd	4.5	0 Lin1	190	26	71	4095	35.246
N20tSh8.ddd	4.5	0 Lin1	190	26	71	200	2.042
N20tSh9.ddd	4.5	0 Lin1	190	26	71	3600	31.027

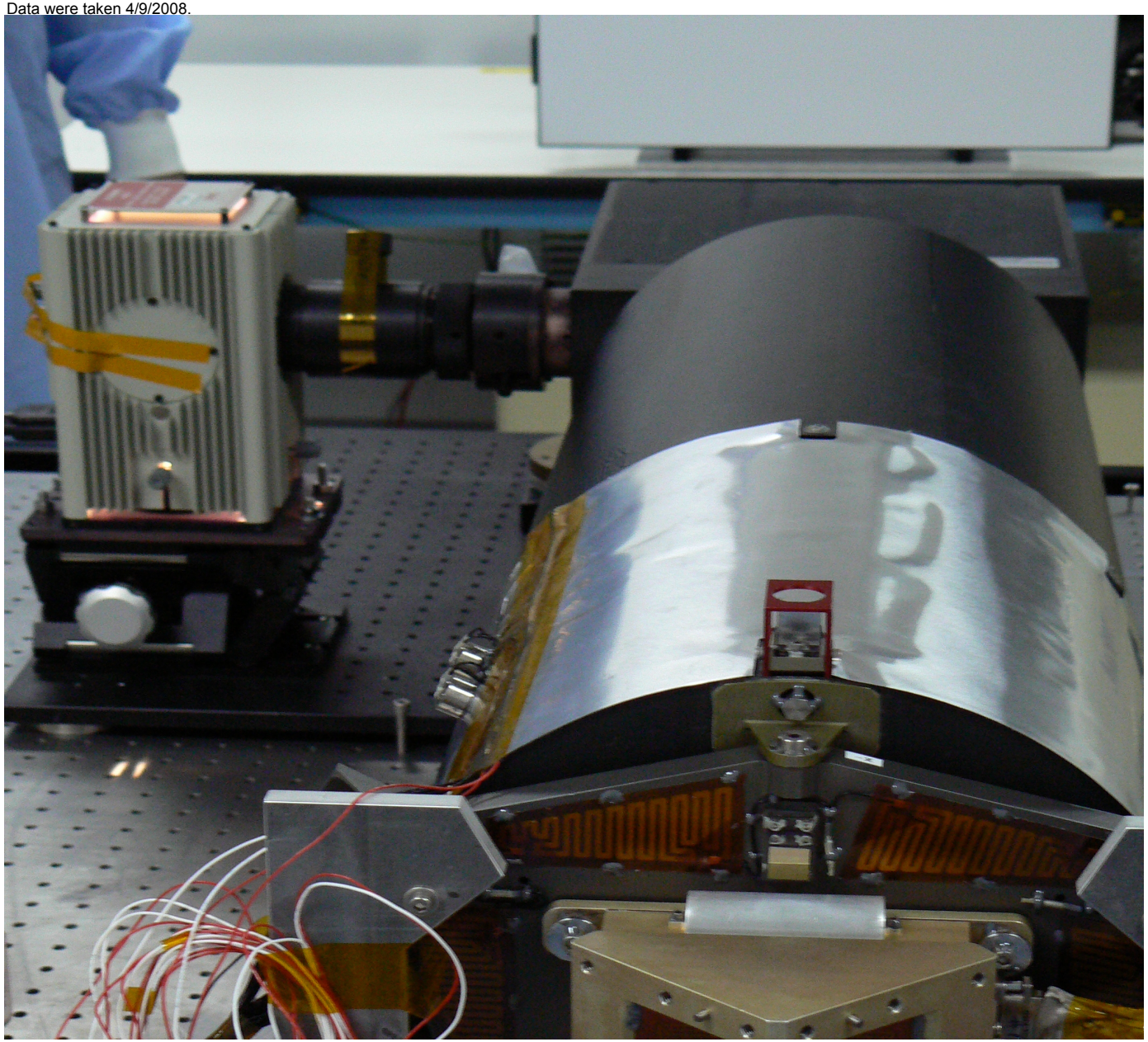
N20tSh10.ddd	4.5	0	Lin1	190	26	71	1200	10.567
N20tSh11.ddd	4.5	0	Lin1	190	26	71	2400	20.797
N20tSh12.ddd	4.5	0	Lin1	190	26	71	2800	24.207
N20tSh13.ddd	4.5	0	Lin1	190	26	71	3000	25.912
N20tSh14.ddd	4.5	0	Lin1	190	26	71	3400	29.322
N20tSh15.ddd	4.5	0	Lin1	190	26	71	3200	27.617
N20tSh16.ddd	4.5	0	Lin1	190	26	71	0	0.337
N20tSh17.ddd	4.5	0	Lin1	190	26	71	400	3.747
N20tSh18.ddd	4.5	0	Lin1	190	26	71	800	7.157
N20tSh19.ddd	4.5	0	Lin1	190	26	71	50	0.764
N20tSh20.ddd	4.5	0	Lin1	190	26	71	1800	15.682
N20tSh21.ddd	4.5	0	Lin1	190	26	71	100	1.19
N20tSh22.ddd	4.5	0	Lin1	190	26	71	4095	35.246
N20tSh23.ddd	4.5	0	Lin1	190	26	71	200	2.042
N20tSh24.ddd	4.5	0	Lin1	190	26	71	3600	31.027
N20tSh25.ddd	4.5	0	Lin1	190	26	71	1200	10.567
N20tSh26.ddd	4.5	0	Lin1	190	26	71	2400	20.797
N20tSh27.ddd	4.5	0	Lin1	190	26	71	2800	24.207
N20tSh28.ddd	4.5	0	Lin1	190	26	71	3000	25.912
N20tSh29.ddd	4.5	0	Lin1	190	26	71	3400	29.322
N20tSh30.ddd	4.5	0	Lin1	190	26	71	0	0.337

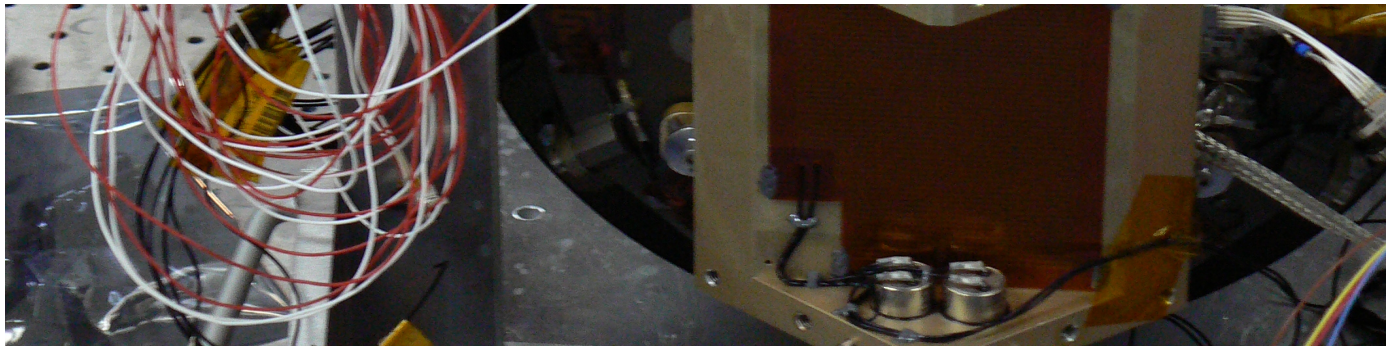
Analysis available as of 8/19/2008
The photon transfer curve analysis for these data is at http://lroc.sese.asu.edu/WORK/CALB/NAC2/photontransfercurve/index.html.

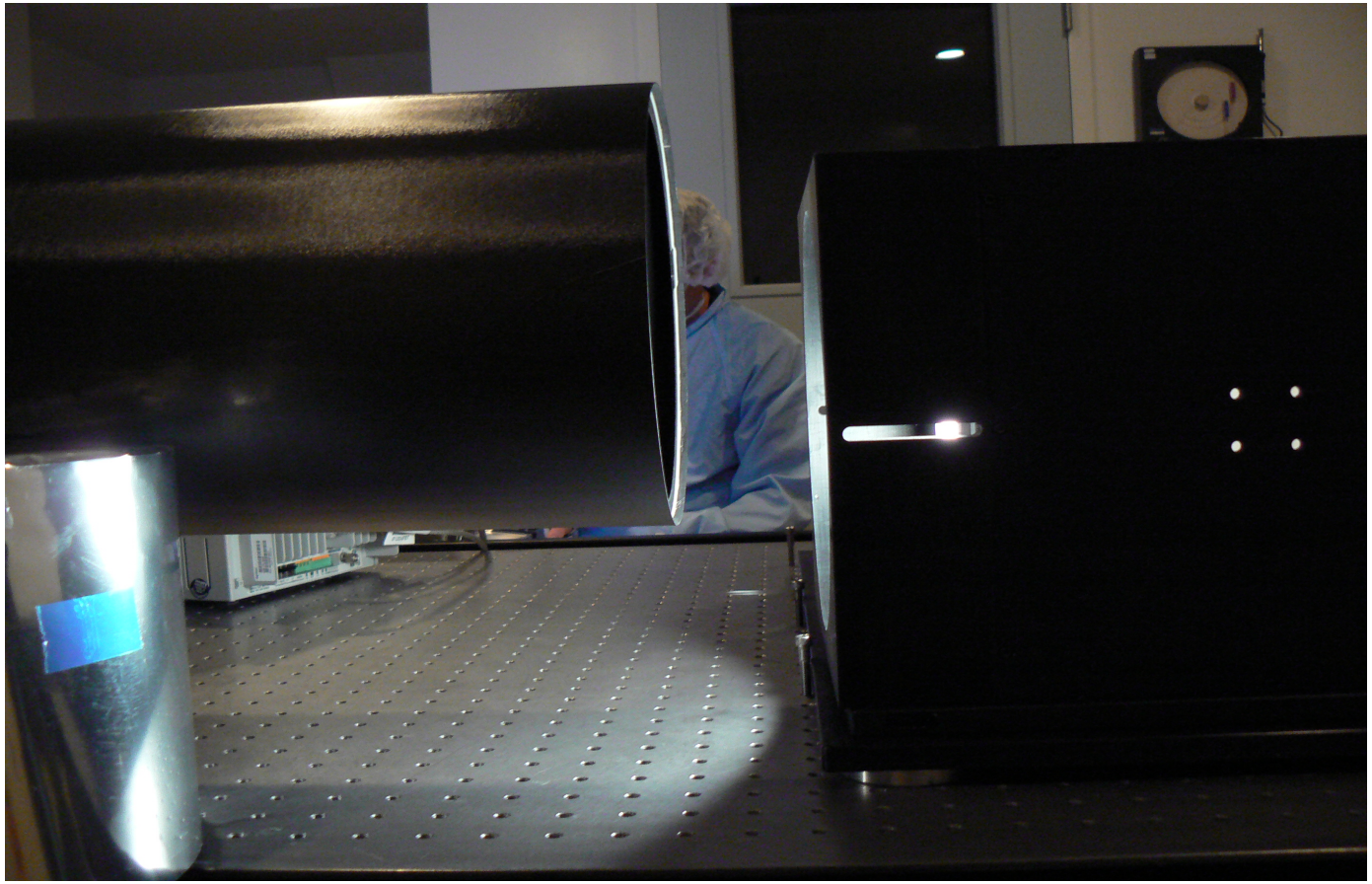
Linearity analysis is at http://lroc.sese.asu.edu/WORK/CALB/NAC2/NAC2-080409-PTC/index.html.

NACFU1 detector linearity calibration with QTH lamp and sphere with 4 inch aperture at multiple DAC levels

Data were taken 4/9/2008.







The quartz tungsten halogen (QTH) lamp is powered by a regulated dc current power supply, and the brightness of the

QTH lamp is highly constant with time. The exposure time given in the embedded ascii header of each
.ddd file is believed to be highly accurate. In the detector linearity test, images are taken at multiple exposure times.
The light source is constant, so it's possible to plot the DN as a function of relative number of photons detected
(detector linearity) or line-to-line standard deviation of DN as a function of relative number of photons detected
(photon transfer curve, or PTC). Repeating the data set at different lamp current, and dark, allows one to check
For exposure time offset as well as DN offset, and to see if the linearity or PTC changes with frame rate.
Note that for the NAC, the exposure time always equals the frame time.

The source is a fairly uniform flat field, but it's not vital that it be accurately flat for linearity and PTC.

For detector linearity and PTC calculations, the mode 10 and mode 30 data is particularly valuable because it has the full
12 bits of accuracy in DN. For darks, of course, mode 0, lin1 data is just as good because it gives fully accurate
DN for DN<256. Bright images in mode 0, lin16 are not as accurate because the images are entirely multiples of
16 DN.

This data set is larger than the earlier set taken with the QTH shining on the Spectralon panel.
In this set, the whole set of exposure times is repeated at different DAC levels, to check whether the DAC level affects the linearity.
As far as we can tell, it doesn't, it just shifts DN by a constant over the entire range.
Because of the offsets caused by the DAC, most of the images have high DN, including the darks, so the lin1 companding table isn't used, only mode 10 and mode 30.

Calibration parameters				NAC parameters						
Filename	QTH current (A)	Dark	Notes	Mode	Companding tal	DAC	Dc offset A	Dc offset B	Exp command	Exposure time (ms)
N20cSj0.ddd	5.5			10		188			3200	27.617

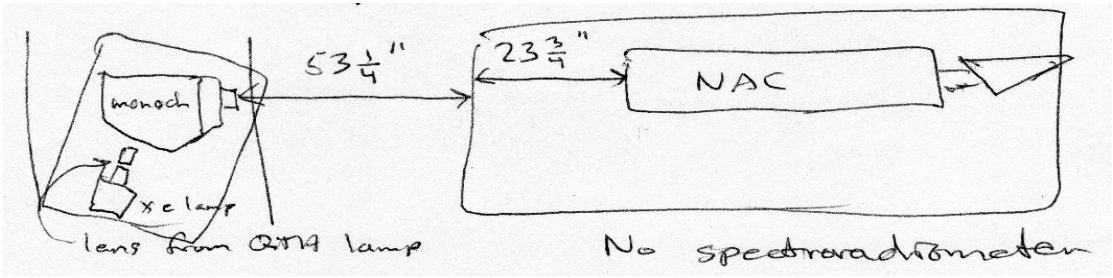
...insert additional filenames and data, starting with page 18 of lab notes http://lroc.sese.asu.edu/WORK/CALB/NAC2/PDF/NAC2-20080409-CalLog.pdf

N20dSq11.ddd	NAC shuttered, room dark, lamp off	30	170			2400	20.797

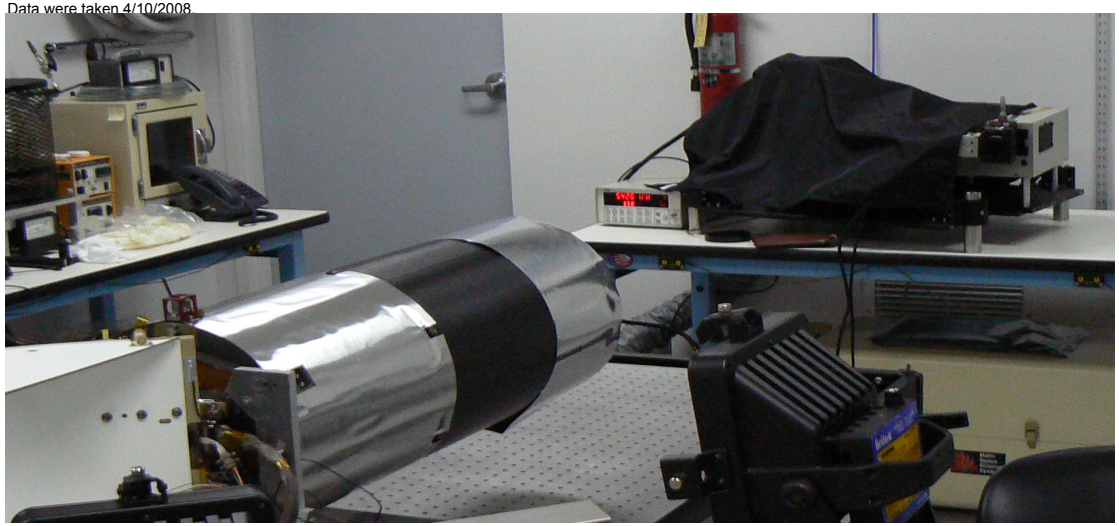
Analysis available as of 8/19/2008

Linearity analysis is at http://lroc.sese.asu.edu/WORK/CALB/NAC2/NAC2-080409-PTC/index.html.

NACFU2 responsivity as a function of wavelength



Data were taken 4/10/2008.



The exit slit of the monochromator is not well characterized geometrically, except that it is compact. It is out of focus, of course.
It was off center so that it would not be blocked by the secondary mirror, and the cone of light filled most of the NAC aperture.
We used the lens from the QTH along with the Xe lamp so that we could have the brightest possible light focused on the entrance
Slit of the monochromator.

These data were taken with both the entrance and exit slits of the monochromator both set to 3 mm unless otherwise noted.
When the entrance slit of the monochromator was increased from 1 mm to 3mm at 600 nm, the beam monitor reading increased by a factor of only
5/3 rather than the expected factor of 3, indicating that the effective entrance slit is determined by the lamp as well as the actual entrance slit.
This could in theory affect the wavelength produced by the monochromator, but only by a fraction of a nm for this setup, which is insignificant.
This is a ¼ meter Czerny-Turner monochromator with a 3-grating turret; details at
http://lroc.sese.asu.edu/WORK/CALB/NAC1/SD/e5385_Oriel-Cornerstone-260-14-m-Monochromator.pdf.
The beam monitor is a calibrated silicon photodiode; details of power meter at http://lroc.sese.asu.edu/WORK/CALB/NAC1/SD/70310.pdf.
Note the beam monitor gives power up to a constant factor, and it's equivalent to radiance as a function of wavelength up to a constant factor.
The beam monitor is believed to be accurate across the entire spectral range.
According to spectroradiometer measurements of the calibrated integrating sphere, the spectroradiometer is accurate
400-700 nm, **except** it overstates the spectral radiance by a factor of 2.4, which doesn't matter for the monochromator measurement.
The monochromator measurement is geometrically uncontrolled and the spectroradiometer samples only a small part of the beam.
Therefore the spectroradiometer measurements are accurate only up to a constant factor anyway.
For wavelengths 700-1100 nm, a longpass order-sorting filter was inserted before the entrance slit of the monochromator.
The filter is Andover 600FH90-50 AM-67408 S/N 03.
For wavelengths 400-700 nm, there is no filter. At 700 nm, we took data both with and without the order-sorting filter.

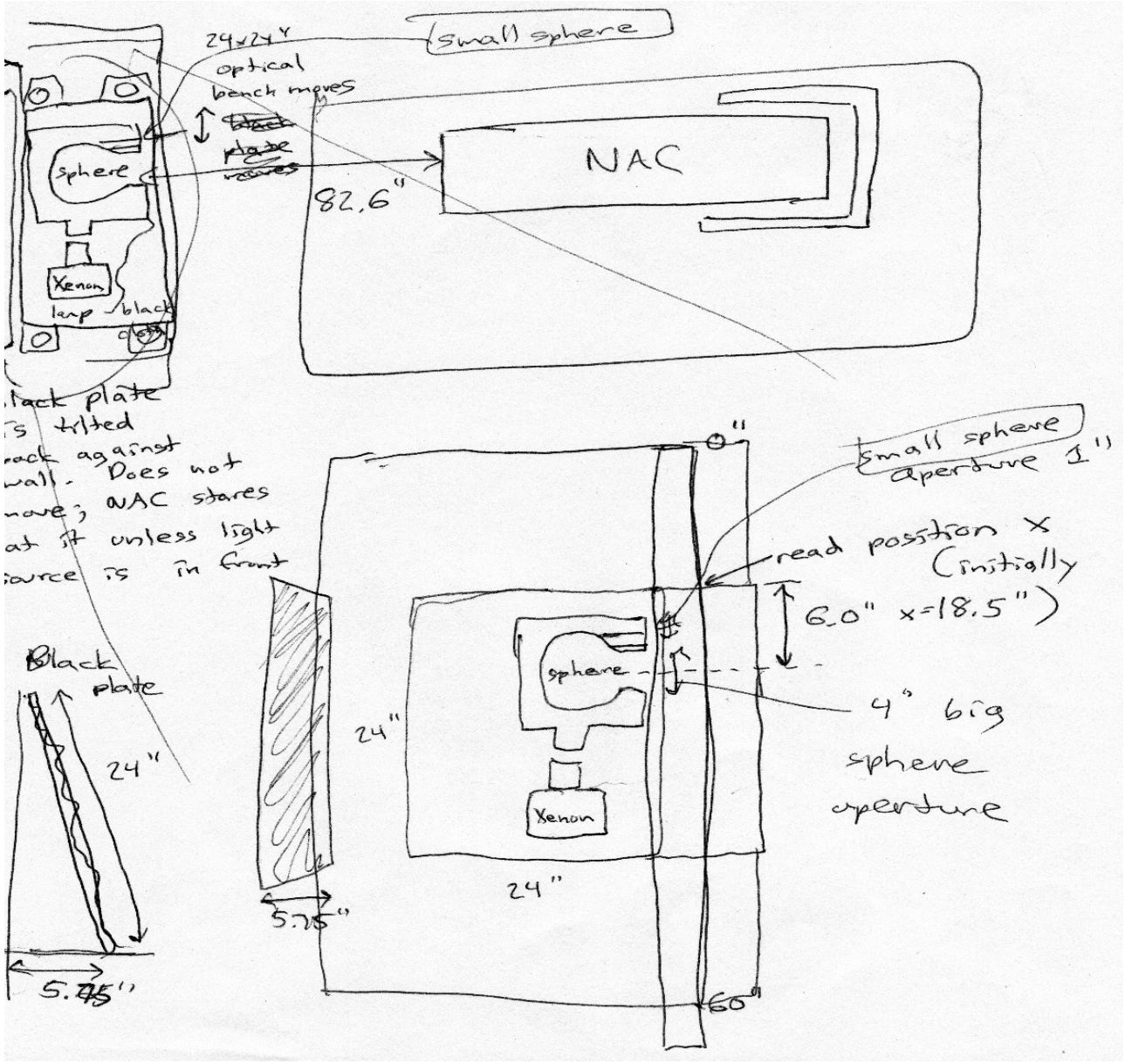
Calibration parameters						NAC parameters						
Filename	Dark	Wavelength (nm	Beam monitor (i	Ultradex stage (	Order sorting fil	Notes	Mode	Companding tal	DAC	Dc offset A	Dc offset B	Exp command	Exposure time (ms)
N24mX0.ddd		350	8.212	357			0	Lin1	190	25	76	1200	10.567
N24mX1.ddd		350	8.212	357			10		190	25	76	1200	10.567
N24mX2.ddd		350	8.212	357			30		190	25	76	1200	10.567
N24mX3.ddd		360	8.287	357			0	Lin1	190	25	76	1200	10.567
N24mX4.ddd		360	8.287	357			10		190	25	76	1200	10.567
N24mX5.ddd		360	8.287	357			30		190	25	76	1200	10.567

...insert additional filenames and data, starting with page 8 of lab notes http://lroc.sese.asu.edu/WORK/CALB/NAC2/PDF/NAC2-20080410-CalLog.pdf

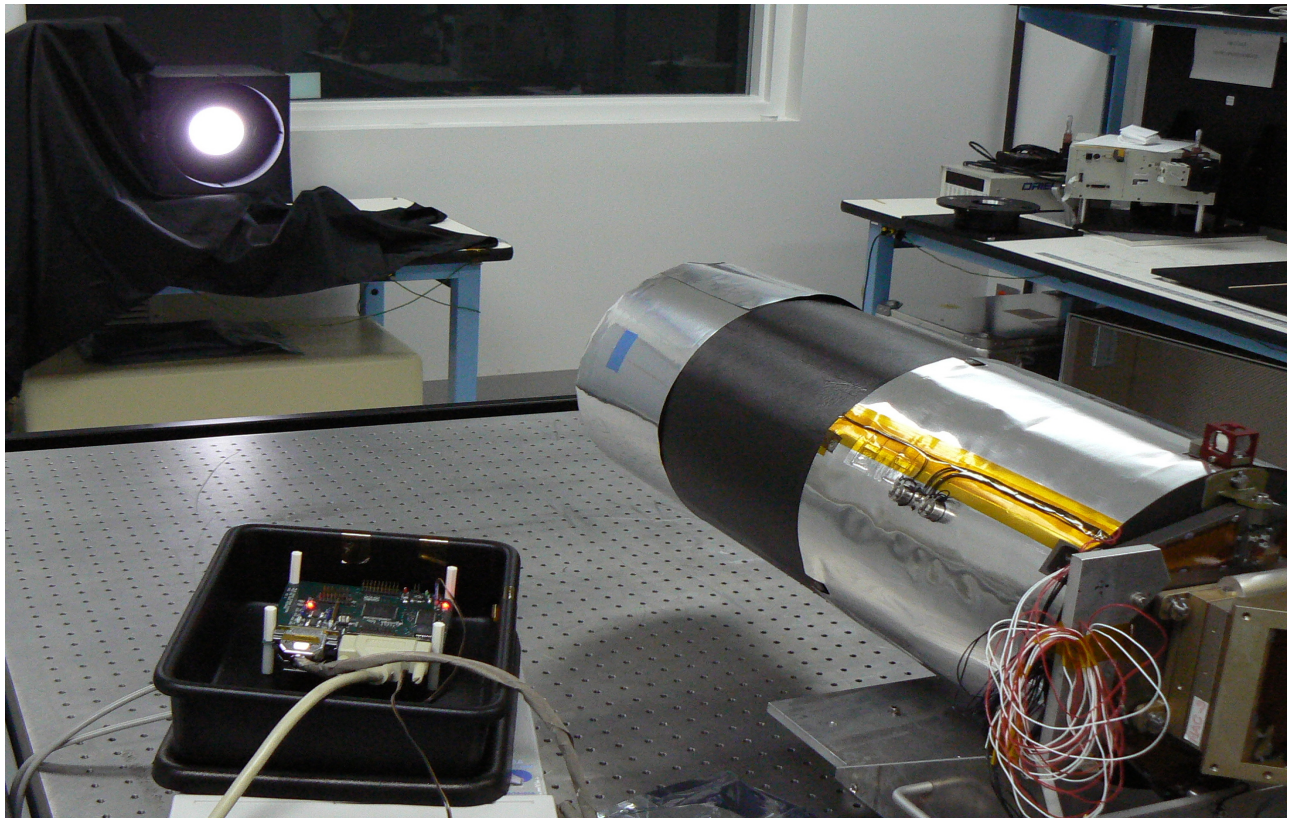
N24mXa16.ddd		1050	0.684	355		0	Lin1	190	25	76	1200	10.567
N24mXa17.ddd		1100	0.3267	355		0	Lin1	190	25	76	1200	10.567
N24dXf0.ddd	NAC and monochromator shuttered					0	Lin1	190	25	76	1200	10.567
N24dXf1.ddd	NAC and monochromator shuttered					0	Lin1	190	25	76	1200	10.567
N24dXf2.ddd	NAC and monochromator shuttered					0	Lin1	190	25	76	1200	10.567
N24dXf3.ddd	NAC and monochromator shuttered					0	Lin1	190	25	76	1200	10.567
N24dXf4.ddd	NAC and monochromator shuttered					0	Lin1	190	25	76	1200	10.567
N24dXf5.ddd	NAC and monochromator shuttered					0	Lin1	190	25	76	1200	10.567

Analysis available as of 8/19/2008
http://lroc.sese.asu.edu/WORK/CALB/NAC2/NAC2-080410-2-spectral/index.html

NACFU2 stray light calibration with sphere with 4 inch and 1 inch apertures and Xe lamp



Data were taken 4/11/2008



Sphere is moved from side to side and position is measured on a long metal ruler. For the 4” aperture, the source is centered at about x=17.5”.
For the 1” aperture, the source is centered at about x=21.2”.

When we change the exposure time parameter from the minimum value of 0 to the maximum value of
4095, the exposure time in ms changes by about a factor of 100. By changing integration time, we can make the measurement more sensitive.
This allows stray light to be measured better at large angles. We can also change between the lin16 and the lin1 companding tables.
That gives a factor of 16.

Calibration parameters

Filename	Dark	Sphere crosstra	Sphere height (i	Notes
N23dXa0.ddd	NAC shuttered, black cloth in front of NAC			
N23dXa1.ddd	NAC shuttered, black cloth in front of NAC			
N23dXa2.ddd	NAC shuttered, black cloth in front of NAC			
N23dXa3.ddd	NAC shuttered, black cloth in front of NAC			
N23dXa4.ddd	NAC shuttered, black cloth in front of NAC			
N23dXa5.ddd	NAC shuttered, black cloth in front of NAC			
N23dXa6.ddd	NAC shuttered, black cloth in front of NAC			
N23dXa7.ddd	NAC shuttered, black cloth in front of NAC			
N23tXa0.ddd		18.5	2.92	

NAC parameters

Mode	Companding tał	DAC	Dc offset A	Dc offset B	Exp command	Exposure time (ms)
0	Lin1	190	0	0	0	0.337
0	Lin1	190	0	0	0	0.337
0	Lin1	190	0	0	0	0.337
0	Lin1	190	0	0	0	0.337
0	Lin1	190	0	0	4095	35.246
0	Lin1	190	0	0	4095	35.246
0	Lin1	190	0	0	0	0.337
0	Lin1	190	0	0	0	0.337
0	Lin16	190	27	76	0	0.337

N23tXa1.ddd	16	2.92		0	Lin16	190	27	76	0	0.337
N23tXa2.ddd	16	2.92		0	Lin16	190	27	76	400	3.747
N23tXa3.ddd	16	2.92		0	Lin16	190	27	76	800	7.157
N23sXa0.ddd	16	2.92		0	Lin16	190	27	76	800	7.157
N23sXa1.ddd	15	2.92		0	Lin16	190	27	76	800	7.157
N23sXa2.ddd	14	2.92		0	Lin16	190	27	76	800	7.157

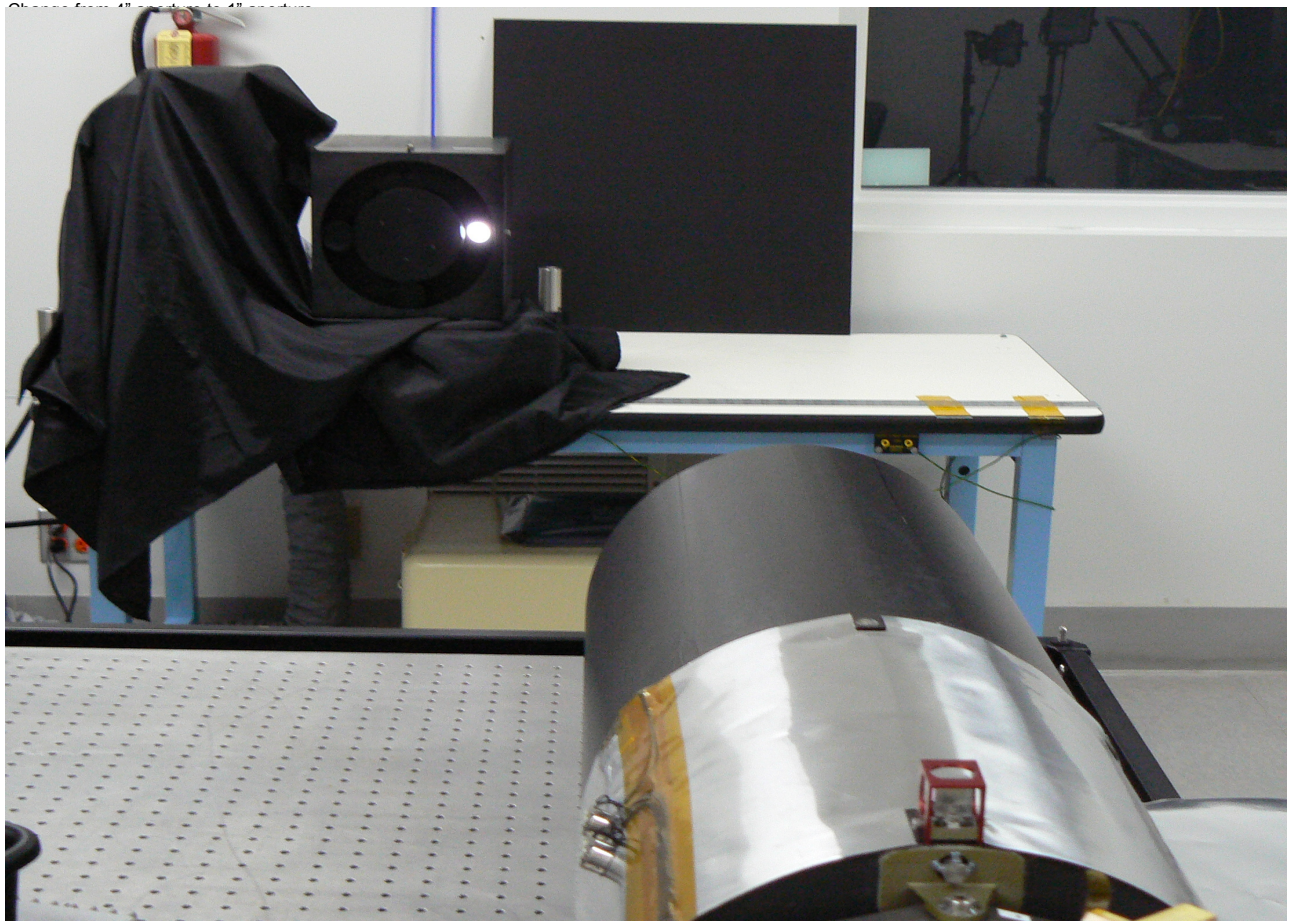
...insert additional filenames and data, starting with page 3 of lab notes http://lroc.sese.asu.edu/WORK/CALB/NAC2/PDF/NAC2-20080411-CalLog.pdf

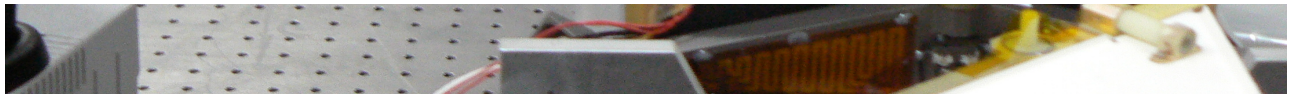
N23sXa20.ddd	17.5	2.92		0	Lin16	190	27	76	800	7.157
N23sXa21.ddd	17.5	2.42		0	Lin16	190	27	76	800	7.157

...insert additional filenames and data, starting with page 4 of lab notes http://lroc.sese.asu.edu/WORK/CALB/NAC2/PDF/NAC2-20080411-CalLog.pdf

N23sXa38.ddd	33	2.42		0	Lin16	190	27	76	800	7.157

Change from 4" aperture to 1" aperture





For the 1” aperture, the source is centered at about x=21.2”.

N23sXb0.ddd	21.5	2.42	0	Lin16	190	27	76	4095	35.246

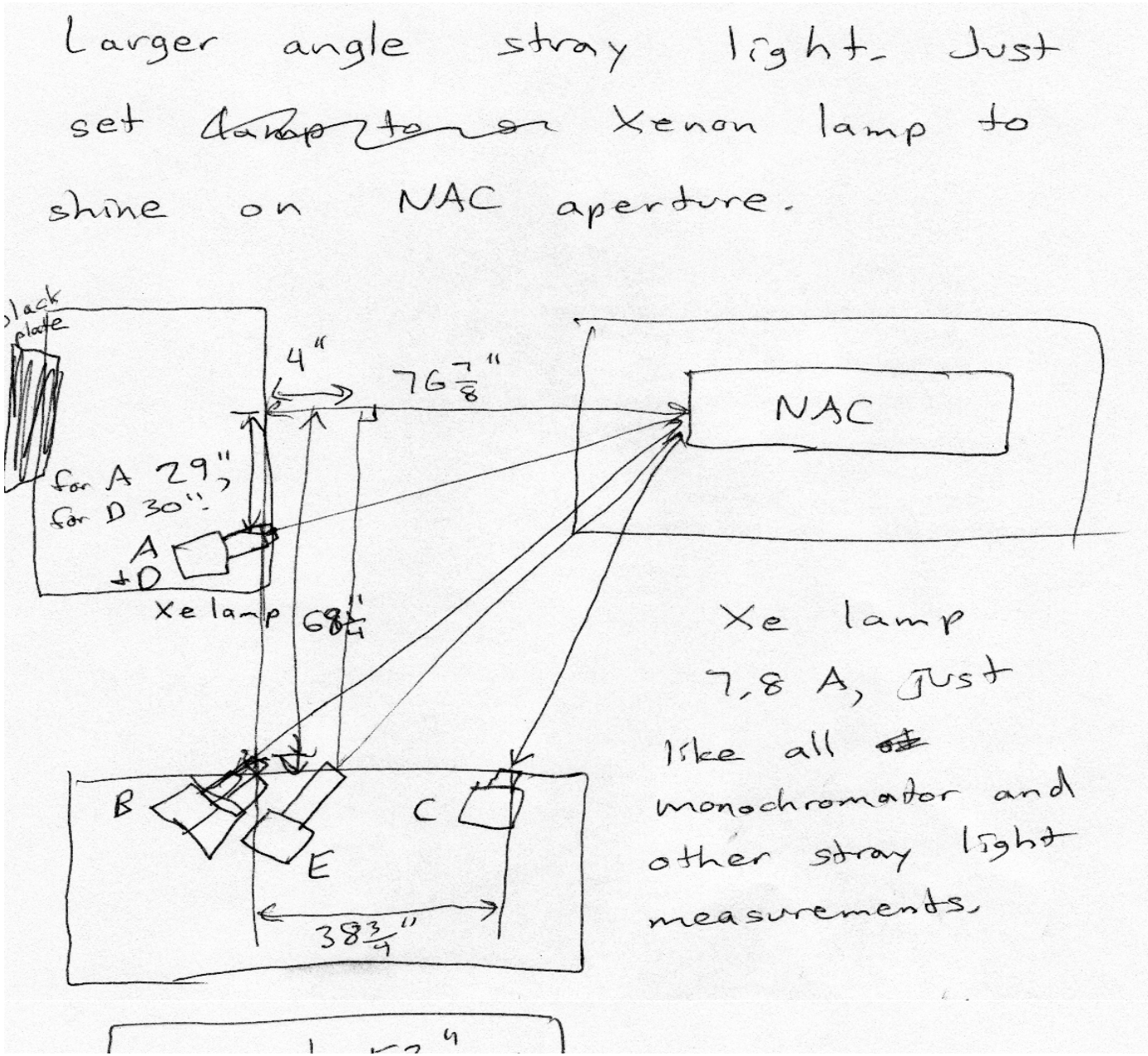
...insert additional filenames and data, starting with page 6 of lab notes http://lroc.sese.asu.edu/WORK/CALB/NAC2/PDF/NAC2-20080411-CalLog.pdf

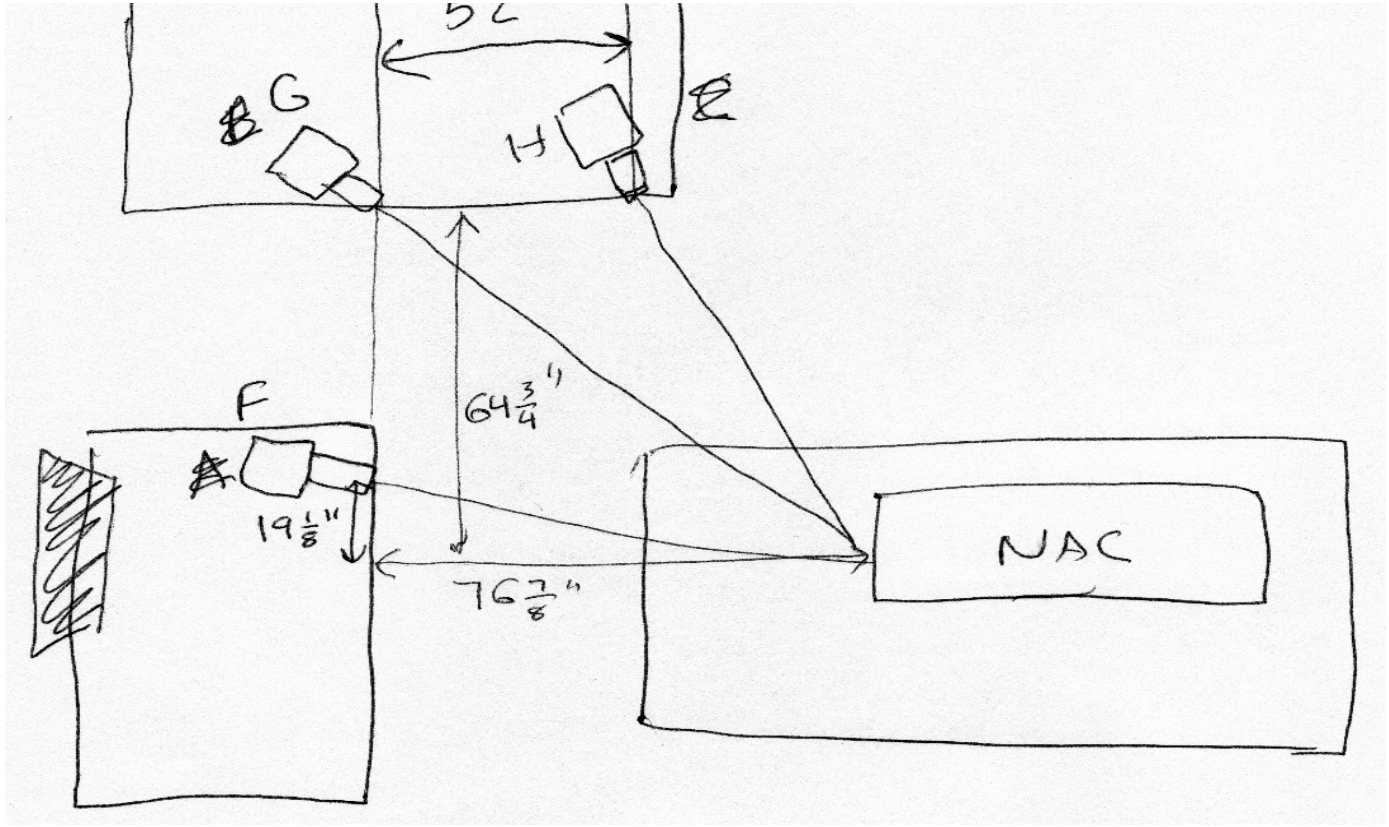
N23sXb28.ddd	14.5	2.42	0	Lin16	190	27	76	4095	35.246
N23sXc0.ddd	14.5	2.42	0	Lin16	190	27	76	4095	35.246
N23sXc1.ddd	14.5	2.9	0	Lin16	190	27	76	4095	35.246
N23sXc2.ddd	14.5	2.9	0	Lin1	190	27	76	4095	35.246
N23sXc3.ddd	14.5	3.4	0	Lin1	190	27	76	4095	35.246
N23sXc4.ddd	14.5	3.9	0	Lin1	190	27	76	4095	35.246
N23sXc5.ddd	14.5	4.3	0	Lin1	190	27	76	4095	35.246
N23sXc6.ddd	14.5	2.42	0	Lin16	190	27	76	4095	35.246
N23dXb0.ddd	NAC shuttered, room dark, lamp off		0	Lin1	190	27	76	4095	35.246
N23dXb1.ddd	NAC shuttered, room dark, lamp off		0	Lin1	190	27	76	800	7.157
N23dXd0.ddd	NAC shuttered, room dark, lamp off		0	Lin1	190	27	76	3200	27.617
N23dXd1.ddd	NAC shuttered, room dark, lamp off		0	Lin1	190	27	76	0	0.337
N23dXd2.ddd	NAC shuttered, room dark, lamp off		0	Lin1	190	27	76	400	3.747
N23dXd3.ddd	NAC shuttered, room dark, lamp off		0	Lin1	190	27	76	800	7.157
N23dXd4.ddd	NAC shuttered, room dark, lamp off		0	Lin1	190	27	76	50	0.764
N23dXd5.ddd	NAC shuttered, room dark, lamp off		0	Lin1	190	27	76	1800	15.682
N23dXd6.ddd	NAC shuttered, room dark, lamp off		0	Lin1	190	27	76	100	1.19
N23dXd7.ddd	NAC shuttered, room dark, lamp off		0	Lin1	190	27	76	4095	35.246
N23dXd8.ddd	NAC shuttered, room dark, lamp off		0	Lin1	190	27	76	200	2.042
N23dXd9.ddd	NAC shuttered, room dark, lamp off		0	Lin1	190	27	76	3600	31.027
N23dXd10.ddd	NAC shuttered, room dark, lamp off		0	Lin1	190	27	76	1200	10.567
N23dXd11.ddd	NAC shuttered, room dark, lamp off		0	Lin1	190	27	76	2400	20.797
N23dXd12.ddd	NAC shuttered, room dark, lamp off		0	Lin1	190	27	76	0	0.337

Analysis available as of 8/19/2008
http://lroc.sese.asu.edu/WORK/CALB/NAC2/straylight/index.html
The first plot on the page is taken from this data set, and just shows the existence of the ghost.
A qualitative look at these images did not indicate any other significant stray light feature.

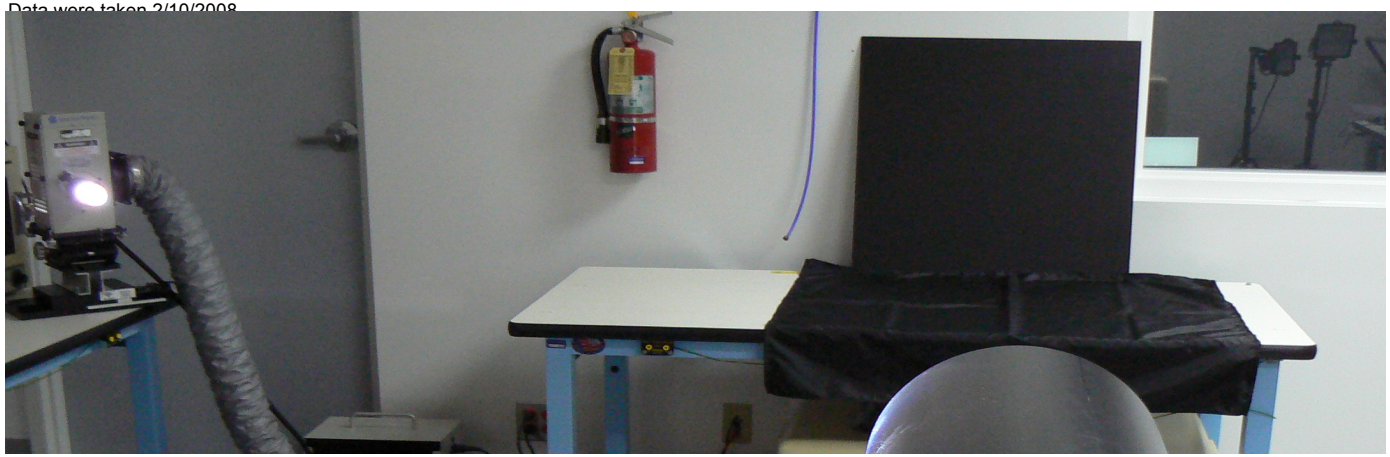
As of 8/19/2008, there has not been a detailed quantitative analysis.

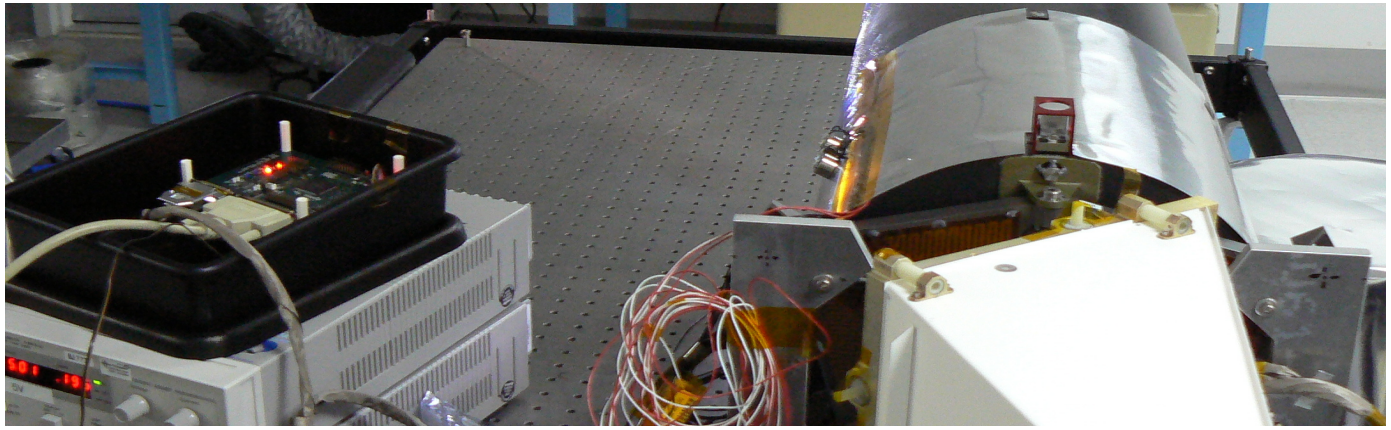
NACFU2 stray light calibration at large angles with direct Xe lamp

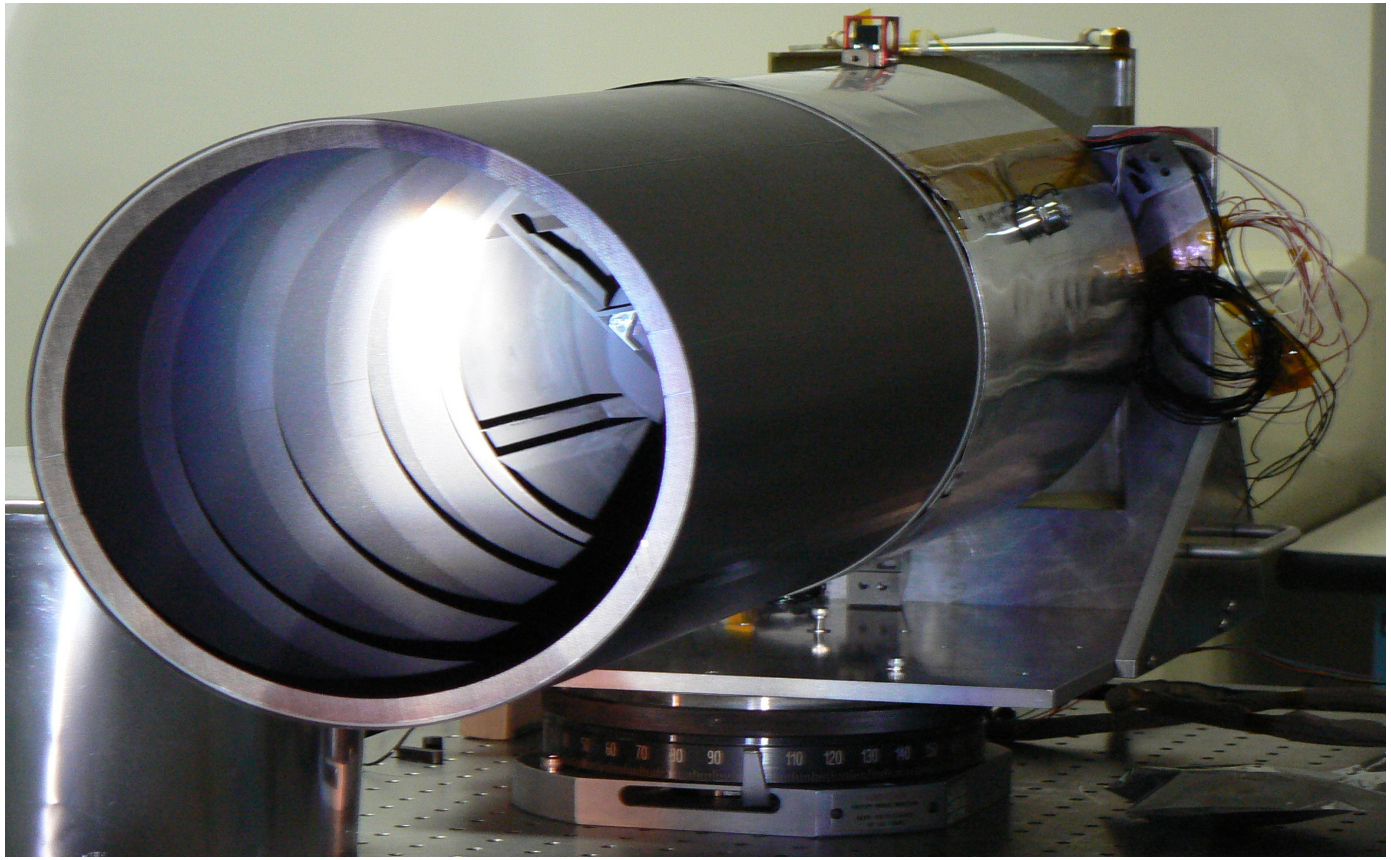




Data were taken 2/10/2008







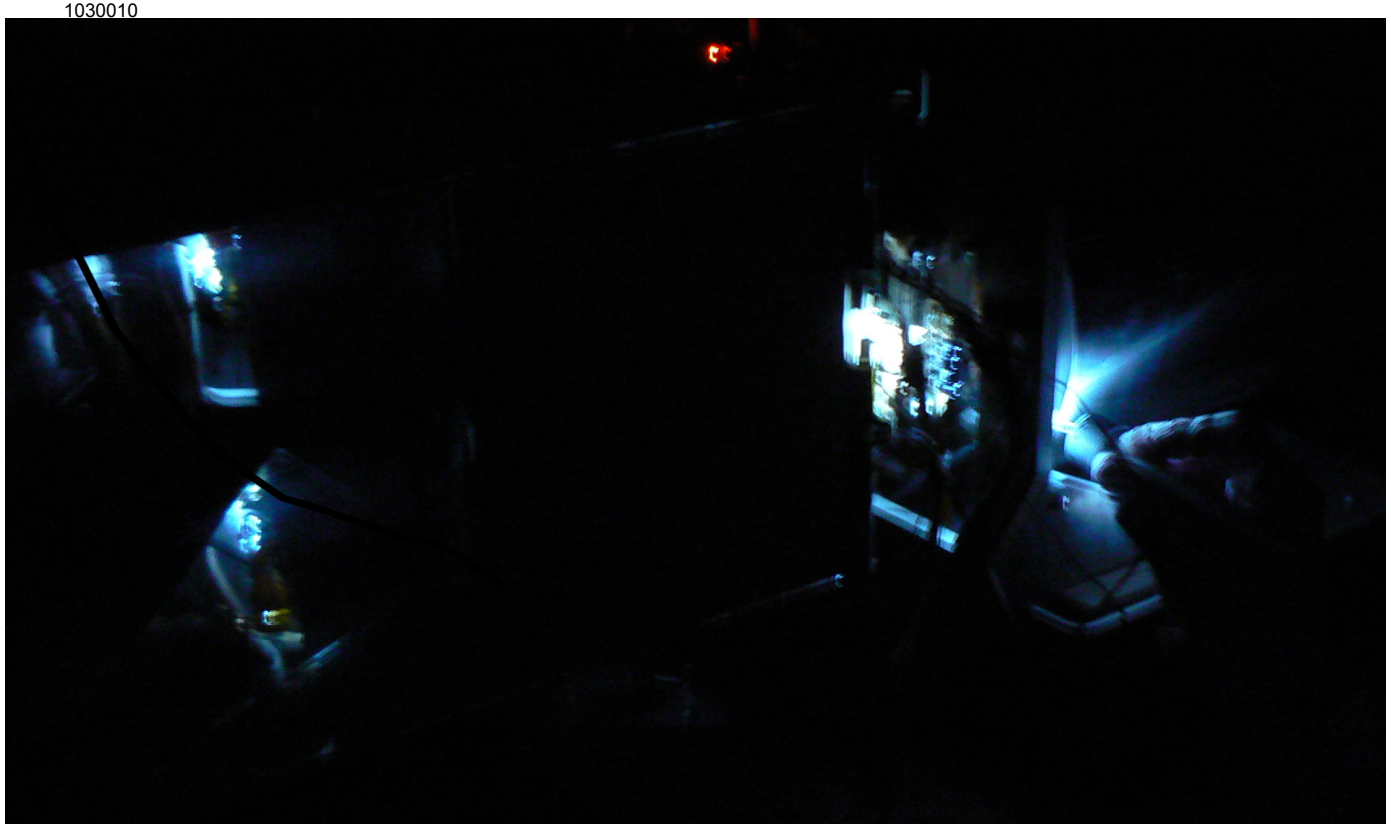
The Xe lamp current is 7.8 amperes for all these data.

Calibration parameters				NAC parameters						
Filename	Dark	Lamp crosstrac	Notes	Mode	Companding tal	DAC	Dc offset A	Dc offset B	Exp command	Exposure time (ms)
N23dXc0.ddd	Lamp off, NAC shuttered			0	Lin1	190	27	76	4095	35.246
N23sXd0.ddd		A	Lamp was warming up	0	Lin1	190	27	76	4095	35.246
N23sXd1.ddd		A		0	Lin1	190	27	76	4095	35.246
N23sXd2.ddd		D		0	Lin1	190	27	76	4095	35.246
N23sXd3.ddd		B		0	Lin1	190	27	76	4095	35.246
N23sXd4.ddd		E		0	Lin1	190	27	76	4095	35.246
N23sXd5.ddd		B		0	Lin1	190	27	76	4095	35.246
N23sXd6.ddd		C		0	Lin1	190	27	76	4095	35.246
N23sXd7.ddd		F		0	Lin1	190	27	76	4095	35.246
N23sXd8.ddd		G		0	Lin1	190	27	76	4095	35.246
N23sXd9.ddd		H		0	Lin1	190	27	76	4095	35.246
N23dXd0.ddd	Lamp off, NAC shuttered			0	Lin1	190	27	76	4095	35.246
N23dXd1.ddd	Lamp off, NAC shuttered			0	Lin1	190	27	76	0	0.337
N23dXd2.ddd	Lamp off, NAC shuttered			0	Lin1	190	27	76	4095	35.246
N23dXd3.ddd	Lamp off, NAC shuttered			0	Lin1	190	27	76	0	0.337

Analysis available as of 8/19/2008
No reports; the link would be http://lroc.sese.asu.edu/WORK/CALB/NAC2/NAC2-080411-1-straylight/index.html
This data set has only large scattering angles, with no normalization by in-field source.
A suggestion for quantitative analysis is given on pp 10-11 of http://lroc.sese.asu.edu/WORK/CALB/NAC2/PDF/NAC2-20080411-CalLog.pdf.

NACFU2 light leak calibration with white LED flashlight

1030010



Data were taken 4/12/2008.

We shone the beam of a white LED flashlight onto various spots on the outside of the NAC, with the room dark and the NAC shuttered. No leaked light was observed.
Snapshots are available as numbered files at http://lroc.sese.asu.edu/WORK/CALB/NAC2/PICS/20080412.html

Calibration parameters				NAC parameters						
Filename	Dark	Snapshot numb	Notes	Mode	Companding tal	DAC	Dc offset A	Dc offset B	Exp command	Exposure time (ms)
N23dFa0.ddd	Flashlight off			0	Lin1	190	27	76	0	0.337

...insert additional filenames and data, starting with page 1 of lab notes http://lroc.sese.asu.edu/WORK/CALB/NAC2/PDF/NAC2-20080412-CalLog.pdf

N23dFa85.ddd	Flashlight off		Room door possibly opened dur	0	Lin1	190	27	76	0	0.337
N23lFa0.ddd		1030009		0	Lin1	190	27	76	4095	35.246
N23lFa1.ddd		1030010		0	Lin1	190	27	76	4095	35.246

N23lFa2.ddd		1030011		0	Lin1	190	27	76	4095	35.246
N23lFa3.ddd		1030012		0	Lin1	190	27	76	4095	35.246
N23lFa4.ddd		1030013		0	Lin1	190	27	76	4095	35.246
N23lFa5.ddd		1030014		0	Lin1	190	27	76	4095	35.246
N23lFa6.ddd		1030015		0	Lin1	190	27	76	4095	35.246
N23lFa7.ddd		1030016		0	Lin1	190	27	76	4095	35.246
N23lFa8.ddd		1030017		0	Lin1	190	27	76	4095	35.246
N23lFa9.ddd		1030018		0	Lin1	190	27	76	4095	35.246
N23lFa10.ddd		1030019		0	Lin1	190	27	76	4095	35.246
N23lFa11.ddd		1030020		0	Lin1	190	27	76	4095	35.246
N23lFa12.ddd		1030021		0	Lin1	190	27	76	4095	35.246
N23lFa13.ddd		1030022		0	Lin1	190	27	76	4095	35.246
N23lFa14.ddd		1030023		0	Lin1	190	27	76	4095	35.246
N23lFa15.ddd		1030024		0	Lin1	190	27	76	4095	35.246
N23lFa16.ddd		1030025	Possible illuminated aperture co	0	Lin1	190	27	76	4095	35.246
N23lFa17.ddd		1030026	Possible illuminated aperture co	0	Lin1	190	27	76	4095	35.246
N23dFb0.ddd	Flashlight off			0	Lin1	190	27	76	4095	35.246

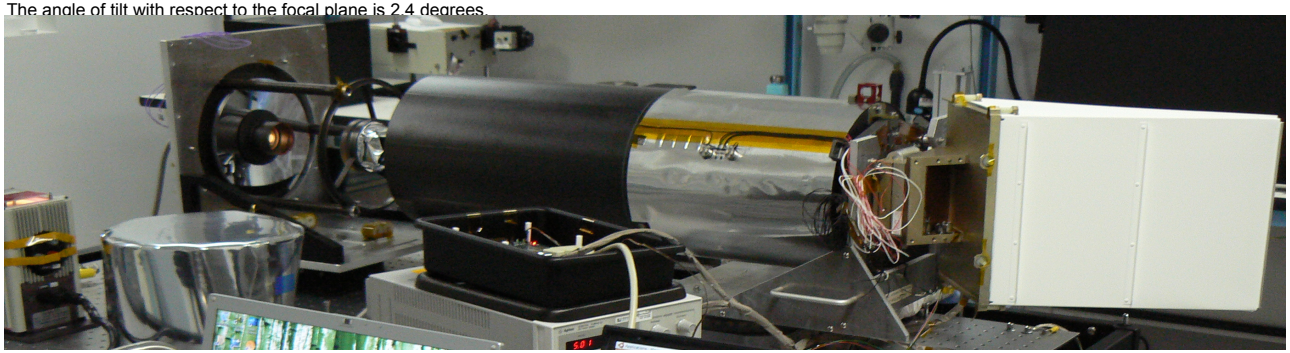
...insert additional filenames and data, starting with page 3 of lab notes http://lroc.sese.asu.edu/WORK/CALB/NAC2/PDF/NAC2-20080412-CalLog.pdf

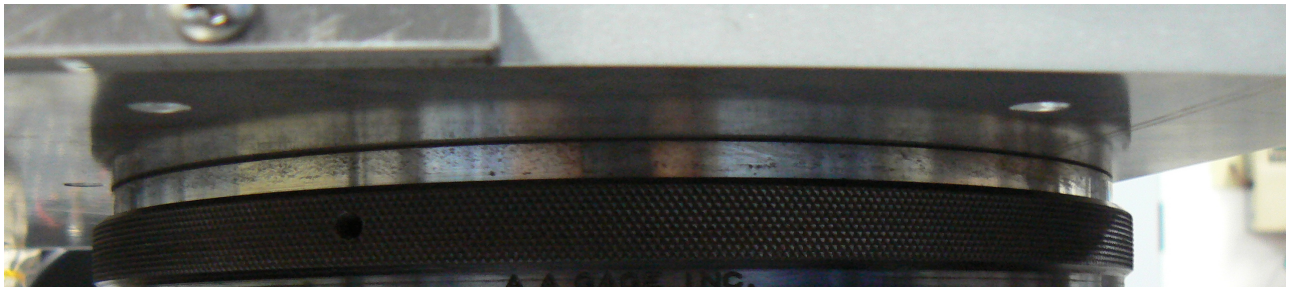
N23dFc10.ddd	Flashlight off			0	Lin1	190	27	76	0	0.337

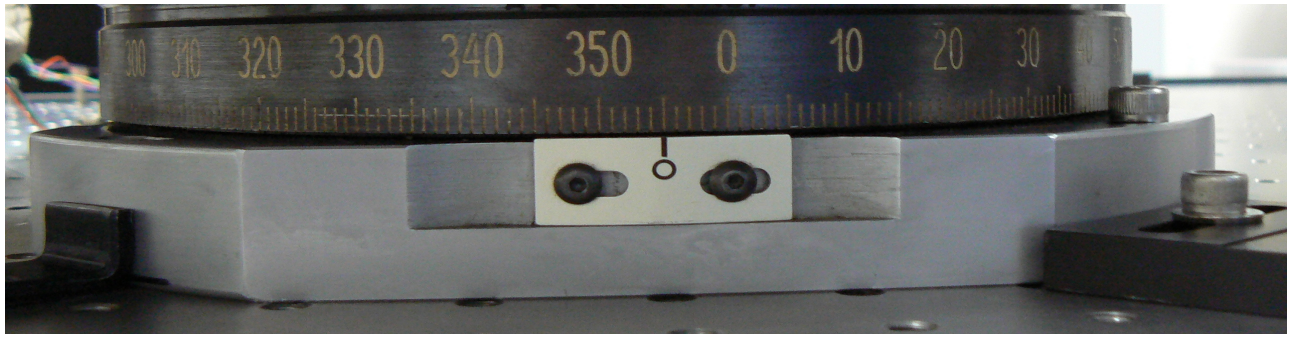
Analysis available as of 8/20/2008
No written report but briefly mentioned at http://lroc.sese.asu.edu/WORK/CALB/NAC2/NAC2-080412-lightleak+darktest/index.html

NACFU2 geometric calibration

Data were taken 4/13/2008.
The NACFU1 instrument was set up on the Ultradex rotation stage looking at the NAC collimator.
The NAC collimator had a bar target approximately at its focus, but tilted with respect to
Its focal plane so one bar is in best focus and the rest are more or less out of focus.
The bars are alternately clear and opaque black, and they are illuminated from behind.
The angle of tilt with respect to the focal plane is 2.4 degrees.







The Ultradex stage allows extremely accurate calibrated rotations of 1 inch each.
That's a bit too coarse for geometric calibration of the 2.8 degree NAC field of view.
We performed 20 unmeasured rotations of the base of the stage.
The axis of the unmeasured rotations was fixed by plates bolted to the optical table.
For each unmeasured rotation position, the base of the Ultradex stage was bolted down and we took an
Image at each of several rotation positions separated by exactly 1 degree, achieved by rotating the
Ultradex stage.

Calibration parameters				NAC parameters						
Filename	Ultradex angle (	Unconstrained r	Dark	Notes	Mode	Companding tał	DAC	Dc offset A	Dc offset B	Exp command	Exposure time (ms)
N22gQa0.ddd	355	1			0	Lin16	190	27	76	300	2.895
N22gQa1.ddd	356	1			0	Lin16	190	27	76	300	2.895
N22gQa2.ddd	357	1			0	Lin16	190	27	76	300	2.895
N22gQa3.ddd	357	2			0	Lin16	190	27	76	300	2.895

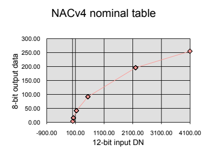
...insert additional filenames and data, starting with page 3 of lab notes http://lroc.sese.asu.edu/WORK/CALB/NAC2/PDF/NAC2-20080413-CalLog.pdf

N22gQa73.ddd	355	22		0	Lin16	190	27	76	300	2.895
N22dQa0.ddd			Room dark, cover on	0	Lin1	190	27	76	300	2.895
N22dQa1.ddd			Room dark, cover on	0	Lin1	190	27	76	3200	27.617
N22dQa2.ddd			Room dark, cover on	0	Lin1	190	27	76	0	0.337
N22dQa3.ddd			Room dark, cover on	0	Lin1	190	27	76	400	3.747
N22dQa4.ddd			Room dark, cover on	0	Lin1	190	27	76	800	7.157
N22dQa5.ddd			Room dark, cover on	0	Lin1	190	27	76	50	0.764
N22dQa6.ddd			Room dark, cover on	0	Lin1	190	27	76	1800	15.682
N22dQa7.ddd			Room dark, cover on	0	Lin1	190	27	76	100	1.19
N22dQa8.ddd			Room dark, cover on	0	Lin1	190	27	76	4095	35.246
N22dQa9.ddd			Room dark, cover on	0	Lin1	190	27	76	200	2.042
N22dQa10.ddd			Room dark, cover on	0	Lin1	190	27	76	3600	31.027
N22dQa11.ddd			Room dark, cover on	0	Lin1	190	27	76	1200	10.567
N22dQa12.ddd			Room dark, cover on	0	Lin1	190	27	76	2400	20.797
N22dQa13.ddd			Room dark, cover on	0	Lin1	190	27	76	0	0.337
N22dQa14.ddd			Room dark, cover on	0	Lin1	190	27	76	300	2.895

Analysis available as of 8/20/2008
http://lroc.sese.asu.edu/WORK/CALB/NAC2/NAC2-080413-geometrical/nacgeometrical_full.doc

NAC LUTs
maxDN 4095 (12-bit)
Use linear segments with inverse slopes 1, 2, 4, 8, 16, and 32
truly full well 300K e NAC
For 2x2 pixel binning, choose table assuming twice the DN of full-resolution mode for the same scene
(twice integration time and two crosstrack pixels are summed, but companding acts on 12 highest bits of 13-bit sum, effectively dividing by 2)
Lunar DN values for full-resolution based on MoonExp.23_320nm_30wide.pdf by Mike Ravine, et al

read noise	100
gain	75
Offset (12-bit	8



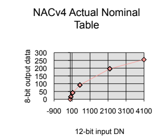
Uses 5 slopes and covers 0-4095: this is Mike Caplinger's engineering model table; good for general use?
Nominal: e < 40000 (avg highlands at 30 degree incidence) has Nq <= 1.3 * Ne (quantz <= 4.3 * noise)

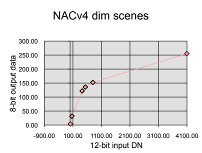
e signal	noise e	SNR	12-bit DN	Noise equiv	C(DN14)	DN8	Quantizatio	RSS N	Nq/Ne (lowe	SNR	SNR%	Slope	Intercept	
0.00	100.00	0.00	8.00	1.33	2.00	4.00	0.60	1.46	0.45	0.00				
2362.50	111.19	21.25	31.50	1.48	2.00	15.75	0.60	1.60	0.40	14.69	0.692	0.5	0.0	2
2362.50	111.19	21.25	31.50	1.48	4.00	15.75	1.20	1.91	0.81	12.32	0.580			
10162.50	141.99	71.57	135.50	1.89	4.00	41.75	1.20	2.24	0.63	56.88	0.795	0.25	7.9	4
10162.50	141.99	71.57	135.50	1.89	8.00	41.75	2.40	3.06	1.27	41.71	0.583			
40162.50	223.97	179.32	535.50	2.99	8.00	91.75	2.40	3.83	0.80	137.69	0.768	0.125	24.8	8
40162.50	223.97	179.32	535.50	2.99	16.00	91.75	4.80	5.65	1.61	93.31	0.520			
164962.50	418.29	394.38	2199.50	5.58	16.00	195.75	4.80	7.36	0.86	297.83	0.755	0.0625	58.3	16
164962.50	418.29	394.38	2199.50	5.58	32.00	195.75	9.60	11.10	1.72	197.39	0.501			
307125.00	563.14	545.38	4095.00	7.51	32.00	254.98	9.60	12.19	1.28	335.34	0.615	0.03125	127.0	32

		16-bit word	Opcode	Term select	Pad	Value
Bterm1	0	16896	2	1	0	0
Bterm2	8	17416	2	2	0	8
Bterm3	25	17945	2	3	0	25
Bterm4	59	18491	2	4	0	59
Bterm5	128	19072	2	5	0	128
Xterm0	0	28672	7	0		0
Xterm1	32	29188	7	1		4
Xterm2	136	29713	7	2		17
Xterm3	536	30275	7	3		67
Xterm4	2200	30995	7	4		275

Actual inputs and outputs

12-bit DN	8-bit data
0	0
31	15
32	16
135	41
136	42
535	91
536	92
2199	196
2200	196
4095	255





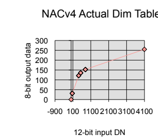
Uses 5 slopes and covers 0-4095; optimized for DN<500
Dark: e < 40000 (avg highlands at 30 degree incidence) has Nq <= 0.9 * Ne (quantz <= 3 * noise)

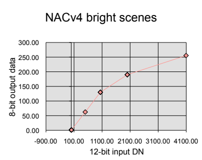
e signal	noise e	SNR	12-bit DN	Noise equiv	C(DN14)	DN8	Quantizatio	RSS N	Nq/Ne (lowe	SNR	SNR%	Slope	Intercept	
0.00	100.00	0.00	8.00	1.33	2.00	4.00	0.60	1.46	0.45	0.00				
4762.50	121.50	39.20	63.50	1.62	2.00	31.75	0.60	1.73	0.37	32.13	0.820	0.5	0.0	2
4762.50	121.50	39.20	63.50	1.62	4.00	31.75	1.20	2.02	0.74	27.53	0.702			
31762.50	204.36	155.43	423.50	2.72	4.00	121.75	1.20	2.98	0.44	139.55	0.898	0.25	15.9	4
31762.50	204.36	155.43	423.50	2.72	8.00	121.75	2.40	3.63	0.88	114.43	0.736			
40162.50	223.97	179.32	535.50	2.99	8.00	135.75	2.40	3.83	0.80	137.69	0.768	0.125	68.8	8
40162.50	223.97	179.32	535.50	2.99	16.00	135.75	4.80	5.65	1.61	93.31	0.520			
59962.50	264.50	226.70	799.50	3.53	16.00	152.25	4.80	5.96	1.36	132.88	0.586	0.0625	102.3	16
59962.50	264.50	226.70	799.50	3.53	32.00	152.25	9.60	10.23	2.72	77.39	0.341			
307125.00	563.14	545.38	4095.00	7.51	32.00	255.23	9.60	12.19	1.28	335.34	0.615	0.03125	127.3	32

		16-bit word	Opcode	Term select	Pad	Value
Bterm1	0	16896	2	1	0	0
Bterm2	16	17424	2	2	0	16
Bterm3	69	17989	2	3	0	69
Bterm4	103	18535	2	4	0	103
Bterm5	128	19072	2	5	0	128
Xterm0	0	28672	7	0		0
Xterm1	64	29192	7	1		8
Xterm2	424	29749	7	2		53
Xterm3	536	30275	7	3		67
Xterm4	800	30820	7	4		100

Actual inputs and outputs

12-bit DN	8-bit data
0	0
63	31
64	32
423	121
424	122
535	135
536	136
799	152
800	153
4095	255



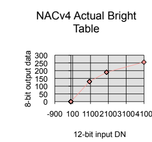


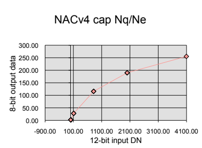
Uses 3 slopes and covers 0-4095; optimized for 500<DN<2000
Bright: 40000 < e < 150000 (avg highlands at 30 degree incidence to bright highlands at 5 degrees incidence) has Nq <= 1.2 * Ne (quantz <= 4 * noise)

e signal	noise e	SNR	12-bit DN	Noise equiv	C(DN14)	DN8	Quantizatio	RSS N	Nq/Ne (lowe	SNR	SNR%	Slope	Intercept	
0.00	100.00	0.00	8.00	1.33	8.00	1.00	2.40	2.75	1.80	0.00				
600.00	102.96	5.83	8.00	1.37	8.00	1.00	2.40	2.76	1.75	0.00	0.000			
600.00	102.96	5.83	8.00	1.37	8.00	1.00	2.40	2.76	1.75	0.00	0.000			
600.00	102.96	5.83	8.00	1.37	8.00	1.00	2.40	2.76	1.75	0.00	0.000			
600.00	102.96	5.83	8.00	1.37	8.00	1.00	2.40	2.76	1.75	0.00	0.000			
37462.50	217.86	171.96	499.50	2.90	8.00	62.44	2.40	3.77	0.83	130.44	0.759			
77962.50	296.58	262.87	1039.50	3.95	8.00	129.94	2.40	4.63	0.61	222.99	0.848	0.125	0.0	8
77962.50	296.58	262.87	1039.50	3.95	16.00	129.94	4.80	6.22	1.21	165.86	0.631			
149962.50	399.95	374.95	1999.50	5.33	16.00	189.94	4.80	7.17	0.90	277.57	0.740	0.0625	65.0	16
149962.50	399.95	374.95	1999.50	5.33	32.00	189.94	9.60	10.98	1.80	181.35	0.484			
307125.00	563.14	545.38	4095.00	7.51	32.00	255.42	9.60	12.19	1.28	335.34	0.615	0.03125	127.5	32

		16-bit word	Opcode	Term select	Pad	Value
Bterm1	0	16896	2	1	0	0
Bterm2	0	17408	2	2	0	0
Bterm3	0	17920	2	3	0	0
Bterm4	65	18497	2	4	0	65
Bterm5	128	19072	2	5	0	128
Xterm0	0	28672	7	0		0
Xterm1	0	29184	7	1		0
Xterm2	0	29696	7	2		0
Xterm3	1040	30338	7	3		130
Xterm4	2000	30970	7	4		250

12-bit DN	8-bit data
0	0
0	0
0	0
0	0
0	0
1039	129
1040	130
1999	189
2000	190
4095	255





Uses 4 slopes and covers 0-4095; cap Nq/Ne for DN<2000
Nominal: e < 150000 (bright highlands at 5 degrees incidence) has Nq <= 1.35 * Ne (quantz <= 4.5 * noise)

e signal	noise e	SNR	12-bit DN	Noise equiv	C(DN14)	DN8	Quantizatio	RSS N	Nq/Ne (lowe	SNR	SNR%	Slope	Intercept	
0.00	100.00	0.00	8.00	1.33	4.00	2.00	1.20	1.79	0.90	0.00				
600.00	102.96	5.83	8.00	1.37	4.00	2.00	1.20	1.82	0.87	0.00	0.000			
600.00	102.96	5.83	8.00	1.37	4.00	2.00	1.20	1.82	0.87	0.00	0.000			
8362.50	135.51	61.71	111.50	1.81	4.00	27.88	1.20	2.17	0.66	47.72	0.773	0.25	0.0	4
8362.50	135.51	61.71	111.50	1.81	8.00	27.88	2.40	3.00	1.33	34.45	0.558			
61162.50	266.76	229.28	815.50	3.56	8.00	115.88	2.40	4.29	0.67	188.19	0.821	0.125	13.9	8
61162.50	266.76	229.28	815.50	3.56	16.00	115.88	4.80	5.97	1.35	135.16	0.590			
149962.50	399.95	374.95	1999.50	5.33	16.00	189.88	4.80	7.17	0.90	277.57	0.740	0.0625	64.9	16
149962.50	399.95	374.95	1999.50	5.33	32.00	189.88	9.60	10.98	1.80	181.35	0.484			
307125.00	563.14	545.38	4095.00	7.51	32.00	255.36	9.60	12.19	1.28	335.34	0.615	0.03125	127.4	32

Bterm1	0	16896	2	1	0	0
Bterm2	0	17408	2	2	0	0
Bterm3	14	17934	2	3	0	14
Bterm4	65	18497	2	4	0	65
Bterm5	128	19072	2	5	0	128
Xterm0	0	28672	7	0		0
Xterm1	0	29184	7	1		0
Xterm2	112	29710	7	2		14
Xterm3	816	30310	7	3		102
Xterm4	2000	30970	7	4		250

12-bit DN	8-bit data
0	0
0	0
0	0
111	27
112	28
815	115
816	116
1999	189
2000	190
4095	255